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***Kirkegaardia* (Polychaeta, Cirratulidae), new name for *Monticellina* Laubier,
preoccupied in the Rhabdocoela, together with new records and
descriptions of eight previously known and sixteen new species
from the Atlantic, Pacific, and Southern Oceans**

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***Kirkegaardia* (Polychaeta, Cirratulidae), new name for *Monticellina* Laubier, preoccupied in the Rhabdo-coela, together with new records and descriptions of eight previously known and sixteen new species from the Atlantic, Pacific, and Southern Oceans**

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Abstract

A new name, *Kirkegaardia*, is proposed to replace *Monticellina* Laubier, 1961, a bitentaculate cirratulid polychaete genus, that is a junior homonym of the turbellarian *Monticellina* Westblad, 1953 (Platyhelminthes, Rhabdocoela). In addition, the opportunity is taken to complete a major revision of the genus including the redescription, revalidation, and separation of three species previously referred to synonymy with *K. dorsobranchialis* (Kirkegaard, 1959) and five other previously described species. In addition, 16 new species are described from the western North Atlantic, eastern and central Pacific, off western South America, and seas around Antarctica, bringing the total number of species in the genus to 38. Included are two new species of the unusual mud ball worms, first reported as *Tharyx luticastellus* Jumars, 1975, from southern California deep basins. A review of all 38 species reveals that three distinct species groups may be identified within the genus in addition to 5–6 species that may eventually be referred elsewhere. This review includes a discussion of the taxonomic characters and various newly defined character states that are found among species of *Kirkegaardia*. Several of these are unique among the Cirratulidae.

Key words: Antarctica, Atlantic Ocean, Pacific Ocean, Mediterranean Sea, Southern Ocean, New England, Puget Sound, Larsen Ice Shelf, Clarion-Clipperton Fracture Zone, Peru-Chile Trench, deep-sea, new species, *Tharyx*, mud ball worm, tessellated tube

Introduction

As part of a continuing revision of bitentaculate Cirratulidae, the genus *Monticellina* Laubier, 1961 was determined to be a junior homonym of *Monticellina* Westblad, 1953 in the Turbellaria. Consequently, a new generic name, *Kirkegaardia*, is here proposed to replace the homonym. Based on new records and type materials, the opportunity is also taken to review several poorly known species in the genus and to describe several new species.

The genus *Monticellina* was originally described to include a single species, *M. heterochaeta* Laubier, 1961 discovered in shallow waters along the French Mediterranean coast. The new genus and species was at the time referred to the family Ctenodrilidae. In a subsequent report, Laubier (1966) determined that his species was similar to several recently described species in the cirratulid genus *Tharyx* and he thus referred his species to that genus as well and *Monticellina* became a synonym of *Tharyx*. Laubier (1966) also compared *T. heterochaeta* with three other known species: *T. dorsobranchialis* (Kirkegaard, 1959) from West Africa, *T. tessellata* Hartman, 1960 from California, and *T. annulosus* Hartman, 1965 from offshore New England. All of these species had capillary setae with distinct teeth or denticles along one edge.

Blake (1991) redefined *Tharyx* Webster & Benedict, 1987 after discovering that the type-species, *T. acutus* Webster & Benedict, 1887, possessed spines with knob-like tips in posterior neuropodia. At the time, *Tharyx* was being defined as having only capillary setae (Hartman 1961). In order to accommodate the species formerly referred to *Tharyx*, Blake (1991) established the genus *Aphelochaeta* for those species having capillaries with smooth or finely fimbriated edges and re-established *Monticellina* for species with capillaries having denticulate or saw-tooth edges. At the same time he described a new species, *M. baptistae* Blake, 1991, from shelf depths off New England and redefined *M. dorsobranchialis* based largely on specimens from the same location; he also and referred both *M. heterochaeta* and *M. annulosa* to synonymy with *M. dorsobranchialis*. In a subsequent report, Blake (1996) recognized that the broader definition of *M. dorsobranchialis* was incorrect and indicated that both *M. heterochaeta* and *M. annulosa* should be separate species. However, to date, these species have not been redescribed.

In recent years, additional species of *Monticellina* have been described (see below) with about 22 species currently recognized as valid. All are now here referred to the new genus name, *Kirkegaardia*. In the present paper, three of the original species, *K. dorsobranchialis*, *K. heterochaeta*, and *K. annulosa* are redescribed together with additional information for six other previously described species. In addition, 16 new species are described from the U.S. Atlantic continental shelf and slope, the northern California continental slope, Puget Sound in the northeastern Pacific, the abyssal Pacific, the southeastern Pacific Ocean off Peru and Chile, and seas around Antarctica. Included among the new species are the specimens from off New England referred to *M. dorsobranchialis* by Blake (1991) and here described as *K. hamptoni* **n. sp.** With these revisions and new species, there are now a total of 38 species referred to *Kirkegaardia* **n. nom.** The characters that define these species are reviewed and discussed together with distinct species groups that can now be recognized.

Material and methods

All specimens were examined with light microscopy using a Wild M-5 stereomicroscope and a Zeiss RA research compound microscope equipped with phase contrast and Nomarski differential interference optics. Photomicrographs were initially taken with a Nikon D80 camera and later a Nikon D7100 camera mounted on both the stereo- and compound microscopes. Some specimens were initially stained with a solution of Shirlastain A in water to highlight difficult-to-see surficial morphology; other specimens were further stained with a saturated solution of Methyl Green (MG) in ethyl alcohol in order to elucidate distinct patterns evident on some species. Both stains dissipate completely in ethyl alcohol. A limited number of scanning electron micrographs (SEM) were prepared using the Zeiss Gemini system at the Marine Biological Laboratory in Woods Hole, Massachusetts. Specimens were critically point dried, coated with gold-palladium, and mounted on stubs. Line drawings were developed in pencil using a drawing tube or camera lucida on the Zeiss RA and later transferred to drawing paper and inked. Plates were prepared and edited using Microsoft PowerPoint, Adobe Acrobat, and Adobe Photoshop software. Measurements were either taken directly with a ruler for large specimens or with calibrated micrometers when specimens were observed on the microscope under a coverslip. For drawings prepared with the camera

lucida, several scales were also sketched directly from stage micrometers at the different magnifications and later used to accurately measure the specimens that were illustrated.

Non-type specimens of *Kirkegaardia heterochaeta* and *K. cf. tessellata* from the Mediterranean coast of France were donated by the late Dr. Lucien Laubier. Types of *Cirratulus dorsobranchialis* from the Zoological Museum and University of Copenhagen (ZMUC) were provided by the late Dr. Mary E. Petersen. Types of *Tharyx annulosus* and *T. luticastellus* were loaned by the Los Angeles Museum of Natural History (LACM). Collections of *Kirkegaardia* from offshore the U.S. Atlantic coast were from (1) monitoring projects in Massachusetts Bay performed for the Massachusetts Water Resources Authority (MWRA), (2) Georges Bank (Georges Bank Benthic Infauna Monitoring Program (GB BIMP) performed for the U.S. Department of the Interior, Minerals Management Service (MMS), and (3) the deep-water U.S. Atlantic Continental Slope & Rise (ACSAR) Program also performed for the MMS. MWRA and MMS collections are lodged with the National Museum of Natural History, Washington, D.C. (USNM); additional MWRA materials are lodged with the Museum of Comparative Zoology, Harvard (MCZ), and LACM. Specimens from off northern California were collected as part of a deep-water monitoring program at the San Francisco Deep Ocean Disposal Site (SF-DODS) and are lodged with LACM. Specimens from Puget Sound, Washington, were provided by Mr. Eugene Ruff and Ms. Margaret Dutch and mostly collected as part of the Washington State Department of Ecology Marine Sediment Monitoring Program (MSMP) and are lodged in the LACM or with MSMP. Specimens from the abyssal plain of the Clarion-Clipperton Fracture Zone in the North Equatorial Pacific Ocean were collected as part of the NOAA Benthic Impact Experiment (BIE) in 1993–1994 and are lodged with the LACM. Specimens from off South America and Antarctica were collected as part of various surveys and expeditions by the R/V *Anton Bruun*, R/V *Hero*, and USNS *Eltanin* and are lodged with the USNM; the specimens from a survey to the Larsen Ice shelf A area on the RVIB *Nathaniel B. Palmer* in May 2000 were collected by the author and are lodged with the LACM. Other Antarctic collections taken as part of surveys by the R/V *Polarstern* are lodged with the Zoological Museum of Hamburg (ZMH); some of these were provided by Dr. Brigitte Ebbe from the EASIZ II survey in 1998; others were collected as part of the author's participation on the ANDEEP I–III surveys in 2002 and 2005. Specimens or SEM stubs labeled as JAB were retained by the author.

Abbreviations used on figures: abdS, abdominal segments; br, branchiae; dPerR, dorsal peristomial ridge; dThorR, dorsal thoracic ridge; gV, germinal vesicle; per, peristomium; latGr, lateral groove; perLips, peristomial lips; pr, prostomium; prob, proboscis; pyg, pygidium; mDCh, mid-dorsal channel; MG, Methyl Green stain; mo, mouth; neuroS, neurosetae; notoS, notosetae; nuO, nuchal organ; thorS, thoracic segments; tn, tentacle; vGr, ventral groove.

Taxonomic account

Kirkegaardia nomen nov.

Type species: *Monticellina heterochaeta* Laubier, 1961.

Monticellina Laubier, 1961, junior **homonym** of *Monticellina* Westblad, 1953.

Diagnosis. Bitentaculate cirratulids with distinct body regions and all setae distally pointed. Pre-setigerous area typically elongate, cylindrical, with short, blunt prostomium and long peristomium with none to many weakly developed annulations; dorsal tentacles arising on posterior margin of peristomium, anterior to setiger 1. Thoracic notopodia often shifted dorsally, elevated, producing distinct dorsal groove along thoracic region; other species with thoracic parapodia more lateral, leaving broad elevated dorsum; parapodia of middle and posterior region lateral. Middle body segments longer than wide, frequently beadlike; posterior segments wider than long, somewhat crowded, with posterior most segments usually expanded or enlarged. Setae including simple capillaries with fibrils observed under SEM and denticulated capillaries with distinct denticles present along one edge of seta; denticles visible at 400–1000x; blades usually basally expanded.

Etymology. *Kirkegaardia*: This genus is named for the late Dr. Jorgen B. Kirkegaard, polychaete specialist and deep-sea biologist of the Zoological Museum of Copenhagen. Dr. Kirkegaard described the first of the bitentaculate cirratulids having denticulate capillary setae: *Cirratulus dorsobranchialis*.

Remarks. The genus *Monticellina* Laubier, 1961 is preoccupied by *Monticellina* Westblad, 1953 in the

Platyhelminthes, Rhabdocoela. Consequently, a new genus name, *Kirkegaardia*, is here proposed to replace the homonym.

Monticellina was established by Laubier (1961) for a new species, *M. heterochaeta*, at the time referred to the family Ctenodrilidae. In a subsequent paper, Laubier (1966) referred *Monticellina* to synonymy with the cirratulid genus *Tharyx* then defined by Hartman (1961) as lacking acicular spines and having only capillary-tipped setae. Laubier (1966) compared his species, *T. heterochaeta*, with three other recently described species: *Cirratulus dorsobranchialis*, *T. tessellata*, and *T. annulosus* all of which were referred to the genus *Tharyx*. These species had the thoracic parapodia shifted dorsally producing a mid-dorsal groove and all possessed denticulated capillary setae.

The genus *Monticellina* was subsequently reinstated by Blake (1991) as part of a revision of species that had been previously assigned to *Tharyx*. Blake restricted *Tharyx* to species having acicular spines that were short, curved and had knob-tipped or irregularly blunted tips as in the type-species *T. acutus*. Other species of *Tharyx* having smooth or finely fimbriated pointed capillary setae were referred to a new genus, *Aphelochaeta* Blake, 1991. *Monticellina* was resurrected for species having capillary setae with denticulated or saw-tooth margins. At the time, Blake (1991) recognized only four species of *Monticellina*: *M. dorsobranchialis* widespread in the Atlantic and Mediterranean; *M. tessellata* from off California; *M. aphelocephalus* (Hutchings & Murray, 1984), from New South Wales, Australia; and *M. baptisteae* Blake, 1991 from the continental shelf and slope of eastern North America. He referred *M. annulosa* and *M. heterochaeta* to synonymy with *M. dorsobranchialis* largely, based on superficial resemblance.

In a subsequent paper, Blake (1996) noted that synonymies proposed in the 1991 paper were being reconsidered such that *M. annulosa* and *M. heterochaeta* would be resurrected from synonymy with *M. dorsobranchialis* and redescribed as a distinct species. In turn, *M. dorsobranchialis* would be restricted in its distribution to off West and South Africa. In the same 1996 paper, Blake reported on six species of *Monticellina* from the Eastern Pacific (two of which were new to science): *M. cryptica* Blake, 1996, *M. luticastella* (Jumars, 1975), *M. secunda* (Banse & Hobson, 1968), *M. serratiseta* (Banse & Hobson, 1968), *M. siblina* Blake, 1996, and *M. tessellata*, redescribed. This revision brought the total number of known or recognized species to 11. Subsequently, additional species of *Monticellina* were described by Dean & Blake (2009), Magalhães & Bailey-Brock (2013, 2015), Lezzi *et al.* (2015), and Elias *et al.* (2016) bringing the total number of named species to 22.

In order to deal with the homonym, all species previously referred to *Monticellina* Laubier are here transferred to *Kirkegaardia* **n. nom.** In addition, redescriptions are presented for eight older and poorly known species including *K. heterochaeta*, *K. dorsobranchialis*, and *K. annulosa*, which were previously synonymized by Blake (1991) and 16 new species bringing the total number of species in *Kirkegaardia* **n. nom.** to 37 (see list below). The following species of *Kirkegaardia* **n. nom.** are currently known:

Kirkegaardia acunai (Dean & Blake, 2009) new combination

Kirkegaardia antelaxa (Dean & Blake, 2009) new combination

Kirkegaardia annulosa (Hartman, 1965) new combination

Kirkegaardia anterobranchiata (Magalhães & Bailey-Brock, 2013) new combination

Kirkegaardia antonbruunae **new species—Off Chile, slope depths**

Kirkegaardia aphelocephala (Hutchings & Murray, 1984) new combination

Kirkegaardia araiotrachela **new species—Off Peru, slope depths**

Kirkegaardia baptisteae (Blake, 1991) new combination

Kirkegaardia brigitteae **new species—Antarctica**

Kirkegaardia carolina **new species—U.S. South Atlantic slope**

Kirkegaardia carinata **new species—Northern California Slope and abyssal depths**

Kirkegaardia carrikeri (Dean & Blake, 2009) new combination

Kirkegaardia chilensis **new species—Off Western Chile**

Kirkegaardia cristata **new species—NE Pacific, Puget sound, WA**

Kirkegaardia cryptica (Blake, 1996) new combination

Kirkegaardia dorsobranchialis (Kirkegaard, 1959) new combination

Kirkegaardia dutchae **new species—NE Pacific, Puget Sound, WA**

Kirkegaardia elongata (Dean & Blake, 2009) new combination

Kirkegaardia fragilis **new species**—Abyssal Pacific
Kirkegaardia franciscana **new species**—Northern California, slope depths
Kirkegaardia giribeti (Dean & Blake, 2009) new combination
Kirkegaardia hampsoni **new species**—U.S. Atlantic shelf, offshore
Kirkegaardia hanaumaensis (Magalhães & Bailey-Brock, 2013) new combination
Kirkegaardia heroae **new species**—Off Tiera del Fuego
Kirkegaardia heterochaeta (Laubier, 1961) new combination
Kirkegaardia jumarsi **new species**—Peru-Chile Trench
Kirkegaardia kladara **new species**—U.S. South Atlantic slope
Kirkegaardia luelledgei (Magalhães & Bailey-Brock, 2015) new combination
Kirkegaardia luticastella (Jumars, 1975) new combination
Kirkegaardia marypetersenae (Lezzi, Çinar, & Giangrande, 2015) new combination
Kirkegaardia morae (Elias, Rivero & Orensanz, 2016) new combination
Kirkegaardia neotesselata **new species**—U.S. North Atlantic slope
Kirkegaardia olgahartmanae **new species**—Antarctica
Kirkegaardia secunda (Banse & Hobson, 1968) new combination
Kirkegaardia serratiseta (Banse & Hobson, 1968) new combination
Kirkegaardia setosa (Dean & Blake, 2009) new combination
Kirkegaardia siblina (Blake, 1996) new combination
Kirkegaardia tessellata (Hartman, 1960) new combination

In order to more effectively deal with the species reported in this paper, they are presented according to the geographic regions where they were collected.

Species of *Kirkegaardia* from the Mediterranean Sea, off West Africa, and the U.S. Atlantic Coast

Kirkegaardia heterochaeta (Laubier, 1961), new combination

Figures 1–2

Monticellina heterochaeta Laubier, 1961: 601–604; Çinar 2005: 150; Ergen *et al.* 2006: 201; Çinar *et al.* 2014: 748.

Tharyx heterochaeta: Laubier 1966: 631–638; Salen-Picard 1981: 83–88; Nicolaidou *et al.* 1989: 29; Salen-Picard *et al.* 1996: 304–305.

Monticellina dorsobranchialis: Blake 1991: 24–26 (In part). Not Kirkegaard (1959).

Monticellina cfr. *heterochaeta*: Dorgham *et al.* 2014: 640.

Material examined. **Mediterranean Sea**, France, Golfe de Fos, west of Marseille, Sta. B, 35 m, coll. C. Salen-Picard, 1979, 10 specimens, donated by L. Laubier (MCZ 135295); same location, Sta. B, 35 m, 7 specimens (MCZ 135296); same location, 42 m 1 specimen (MCZ 135294).

Description. Body elongate, thin throughout with thoracic region only weakly expanded and posteriormost segments slightly enlarged. Longest specimens examined 13 mm long, reported up to 35 mm by Laubier (1966); body narrow, 0.3–0.4 mm wide on specimens examined (0.1–0.4 mm wide reported by Laubier 1966) with 50–70 setigers (30–100 reported by Laubier 1966). Body generally colorless in alcohol.

Thoracic setigers each about 5.5x as wide as long for first 12–15 setigers with parapodia shifted dorsally and elevated above mid-dorsal surface forming distinct mid-dorsal groove on thoracic segments (Fig. 1A); dorsal surface elevated, forming a distinct ridge line inside mid-dorsal groove (Fig. 1A). Ventral surface without grooves or ridges. Abdominal segments becoming longer and narrower, and with parapodia in lateral locations (Fig. 1C). Most abdominal segments up to 2x as long as wide (Fig. 1C), becoming narrower again in expanded posterior most segments (Fig. 1D). Far posterior segments expanded bearing a large rounded pygidium (Fig. 1D).

Pre-setigerous area or head region (prostomium + peristomium) very elongate, narrow, about 2.2x long as wide and same length as first 5–6 following setigerous segments (Fig. 1A–B). Prostomium short, triangular, bluntly rounded on anterior margin (Fig. 1A–B); eyes absent; nuchal organs not observed. Peristomium very elongate, relatively smooth with a single lateral groove in some specimens producing two annular rings (Fig. 1A–B); or no

rings apparent. Narrow dorsal ridge extends from prostomium about half way along dorsal peristomial mid-line (Fig. 1A–B). Paired dorsal tentacles located close together, arising from posterior margin of peristomium (Figs. 1A–B); first pair of branchiae posterolateral to dorsal tentacles at boundary with setiger 1, generally in line with subsequent thoracic branchiae located dorsal to notopodia (Fig. 1A–B). Segmental branchiae of thoracic region on curved edge of each segment, somewhat projecting into mid-dorsal groove. Most branchiae broken, leaving stubs, best seen in thoracic segments and when stained with Shirlastain A; branchiae continue in mid-dorsal location for as long as observed; branchiae rarely observed in abdominal segments.

Parapodia low mounds with noto- and neuropodia closely spaced (Fig. 1E). Thoracic parapodia shifted dorsally; abdominal parapodia more lateral.

Setae all smooth capillaries through thoracic region, numbering about 10–12 in notopodia and same in neuropodia, transitioning to denticulate capillaries in anterior abdominal segments with numbers of setae per fascicle reduced to 6–10. Denticulate setae appear in noto- and neuropodia of anterior abdominal segments from about setigers 11–19 depending on size of worm, appearing more anteriorly on smaller specimens. Denticulate setae with broad shaft and short, curved, downwardly directed denticles along one edge (Fig. 1F–G); notosetae (Fig. 1G) longer and narrower than neurosetae (Fig. 1F); denticulated edge directed ventrally in notosetae and dorsally in neurosetae, thus *vis-à-vis* (Fig. 1E).

Methyl Green stain. A distinctive and intense MG staining pattern evident (Fig. 2A–D). Stained oval green patch on dorsum of second half of peristomium anterior to origin of dorsal tentacles, extending only weakly down lateral sides of peristomium (Fig. 2A, C); no stain on prostomium. Strong staining reaction in thoracic segments, with middle and posterior thoracic segments darkly blue, forming broad bands or stripes extending from mid-dorsum down sides around venter and up opposite side; stain very intense from about setiger 3 to end of thoracic region, weaker on 2–3 segments on either end (Fig. 2A–D); abdominal segments with mid-ventral spot or longitudinal line on individual segments (Fig. 2B–C); thin lines of stain also present intersegmentally in abdominal segments.

Remarks. The body of *Kirkegaardia heterochaeta* is elongate and very slender, with only a minimal expansion of the thoracic region. The species belongs to a group of species with: (1) an elongate prostomial-peristomial region that is relative smooth and weakly divided by annular rings and, (2) dorsally elevated thoracic parapodia that overlie the dorsal surface producing a conspicuous dorsal thoracic groove that contains a mid-dorsal ridge. Laubier (1966) observed superficial lines on *K. heterochaeta* when studied with sagittal thin sections, suggesting that two annular rings were present. However, even with Shirlastain A, annular rings are difficult to detect externally.

Kirkegaardia heterochaeta from shallow-water Mediterranean sediments is morphologically most similar to *K. brigitteae* **n. sp.** from deep-sea habitats in Antarctica and the Southern Ocean. The two species have a distinct mid-dorsal peristomial ridge that extends from the prostomium to about halfway along the peristomium, leaving the rest of the dorsal peristomial surface smooth. Both species also have a mid-dorsal thoracic ridge and similar MG staining patterns. The two species differ in that in *K. heterochaeta* the mid-dorsal thoracic ridge encompasses the entire dorsal surface of the channel, whereas in *K. brigitteae* **n. sp.** there is a separate and narrow ridge on the surface within the channel. Further, the peristomium of *K. heterochaeta* has at least one lateral groove producing two annular rings, whereas *K. brigitteae* **n. sp.** has a smooth peristomium not interrupted by annular rings. The far posterior pre-pygidial segments of *K. brigitteae* **n. sp.** include about 15 segments that are greatly expanded, whereas the same segments of *K. heterochaeta*, although also expanded, are few in number, usually no more than three. The MG staining reactions are basically similar in having the venter of the thorax retaining stain; however, *K. heterochaeta* has an intensely Green stained patch on the dorsal surface of the peristomium, whereas *K. brigitteae* **n. sp.** has only a weak staining reaction that de-stains rapidly. Ten other species features with *K. heterochaeta*; these are compared in the Discussion section of this paper and detailed in Tables 1 and 2.

Biology. *Kirkegaardia heterochaeta* is a relatively common species along the Mediterranean coasts from France to Greece in muddy to muddy-sand sediments and is also reported from the Egyptian coast. Egg diameters of 200–225 µm were recorded for this species by Petersen (1999) from specimens collected in July from the Levantine Basin, eastern Mediterranean, in 65 m by M.E. Çinar. These large eggs suggest that development is direct for this species.

Distribution. Mediterranean Sea, shallow subtidal.

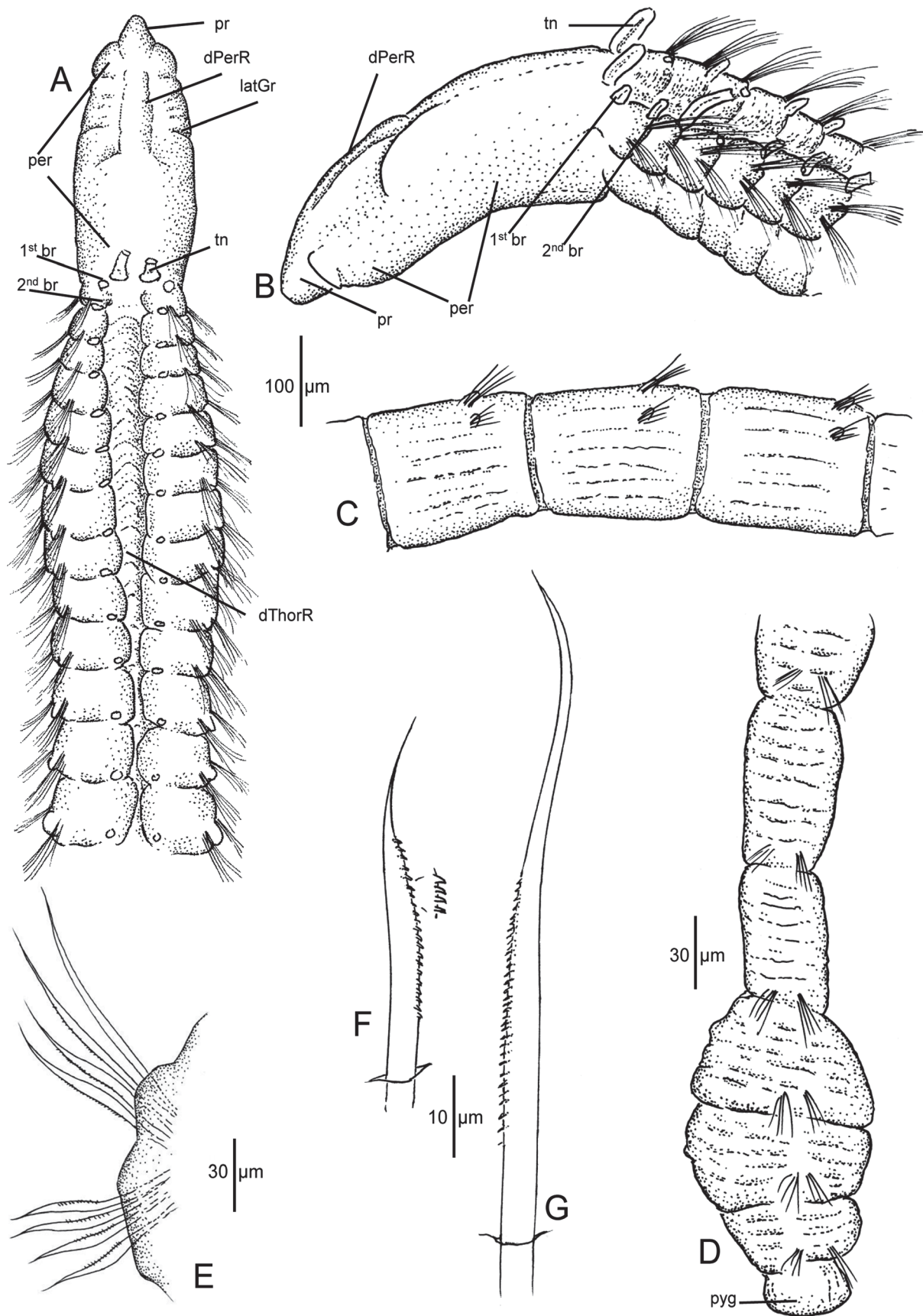


FIGURE 1. *Kirkegaardia heterochaeta* (Laubier, 1961), Golfe de Fos, Sta. 35 (MCZ 35295): A, anterior end, dorsal view; B, anterior end, left lateral view; C, anterior abdominal segments; D, posterior segments and pygidium of a small specimen, right lateral view; E, middle abdominal parapodium, anterior view; F, denticulated neuroseta; G, denticulated notosetae.

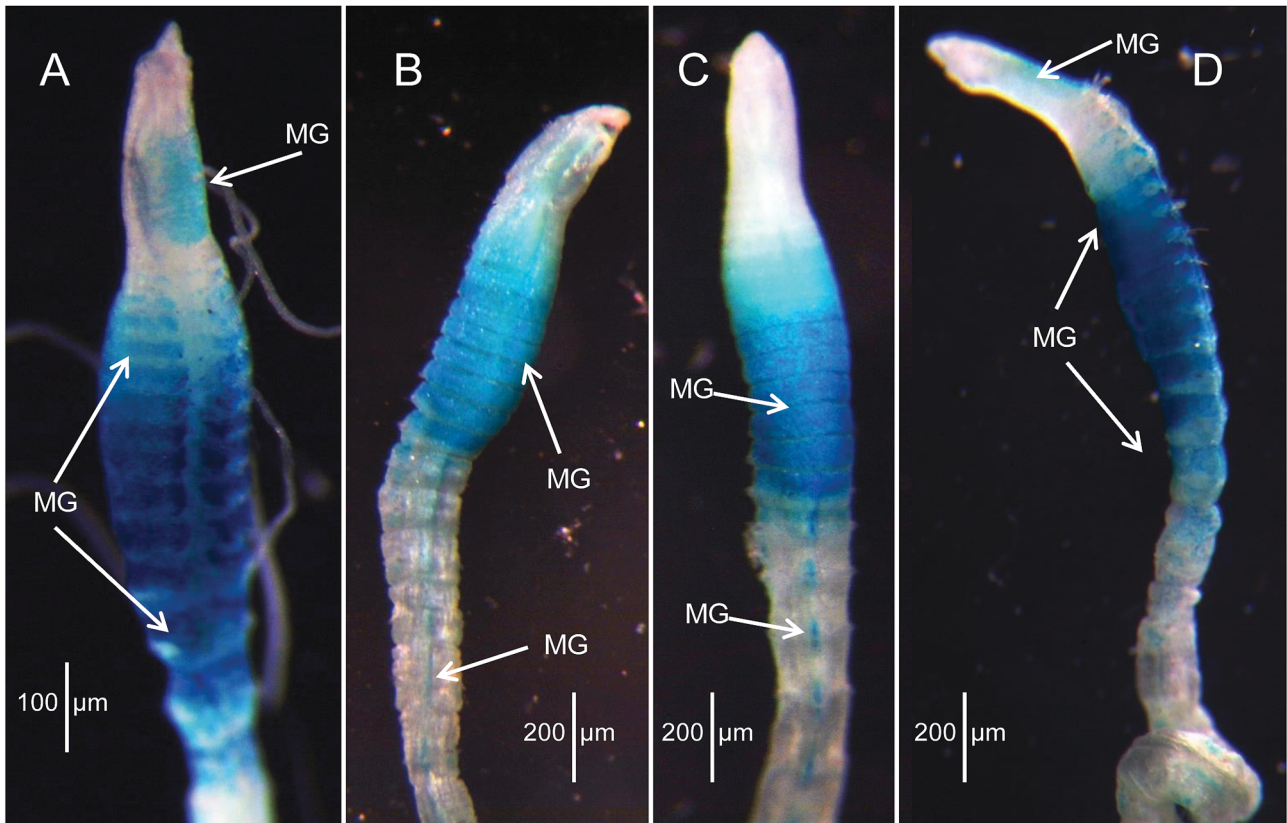


FIGURE 2. *Kirkegaardia heterochaeta* (Laubier, 1961), photomicrographs of specimens from Golfe de Fos showing Methyl Green staining pattern in different views: A, left dorsolateral view; B, right lateral view; C, ventral view; D, left lateral view. (MCZ 35295)

***Kirkegaardia dorsobranchialis* (Kirkegaard, 1959), new combination**

Figures 3–4

Cirratulus dorsobranchialis Kirkegaard, 1959: 34–36, figs. 2–3.

Tharyx dorsobranchialis: Day, 1961: 501–502; 1967: 506, fig. 20f–h; Laubier 1966: 633–637; Day *et al.*, 1970: 30; Hartmann-Schröder 1974: 178; Intes & LeLeouff 1977: 222.

Monticellina dorsobranchialis: Blake 1991: 24–26 (In part); Çinar 2005: 150; Çinar *et al.* 2014: 748.

Material examined. SE Atlantic, West Africa: Off Angola, Bay of Lobito, 12°20'S, 13°40'E, 27 m, 20 Dec. 1950, *Galathea* Expedition Sta. 120, **holotype** and 3 **paratypes** (ZMUC-POL-241–2); same sample, 4 additional **paratypes** (ZMUC-POL-243).

Description. Holotype an incomplete male with rounded, short-headed mature sperm in posterior segments; body colorless in alcohol. Specimen appearing smooth in general outline without conspicuous segmental constrictions or grooves; segments not swollen or beaded (Fig. 3A, C). Anterior 85 segments indistinct under lower magnification (63x) with setae inconspicuous. Holotype incomplete, 58 mm long, 0.6 mm wide across thorax at setigers 18–19 for about 150 setigers. Parapodia of thoracic region shifted dorsally, overlying dorsal surface producing distinct mid-dorsal channel (Fig. 3A). Thoracic region long, with 24 setigers, generally defined by presence of mid-dorsal channel (Fig. 3A, C); first 14 segments short, similar in length but slightly increasing in width; thereafter slightly decreasing in width and gradually increasing in length to chaetiger 24, where segments transition to abdominal segments and become about 2–3x as long as setigers 1–14. More posteriorly segments become larger and increase in length, becoming about as long as wide (Fig. 3D). Paratypes similar in overall morphology. Pygidium not observed.

Pre-setigerous region as long as wide in holotype, up to 1.5x as long as wide in some paratypes. Prostomium of holotype conical, about as long as wide, appearing blunt in dorsal view due to tip of prostomium being bent

ventrally (Fig. 3B); eyespots absent; nuchal organs inconspicuous, appearing at corners of mouth (Fig. 4D). Proboscis elongated, sac-like, appearing cleft ventrally when extended (Fig. 4E). Prostomium not visibly separated from peristomium (Figs. 3A–C, 4D); peristomium smooth; holotype and most paratypes without visible annulations (Figs. 3A–C, 4D); one paratype with faint transverse lines evident (Fig. 4E). Paired dorsal tentacles retained as basal stumps in specimens examined, arising medially on posterior margin of peristomium anterior to setiger 1 (Figs. 3A, C, 4D).

First pair of branchiae arising posterolateral to dorsal tentacle scars anterior to setiger 1; second pair of branchiae on setiger 1 arising medial to notosetae; following thoracic segments with branchiae in same location (Figs. 3A, C, 4D–E). Branchiae dorsal throughout with those of right and left sides most widely separated in anterior segments, gradually approaching mid-dorsum and becoming mid-dorsal by about setiger 20, thereafter continuing mid-dorsally throughout length of specimen (Fig. 3A, C). Branchiae close to notosetae in anterior setigers, then rapidly becoming widely separated from notosetae as branchiae remain in dorsomedial location and parapodia shift to a more lateral location becoming mid-lateral by about setiger 30 (Fig. 3C).

Parapodia reduced, with rami small, close together but distinctly separated throughout; less conspicuous in anterior region, becoming slightly larger and with more setae posteriorly; parapodia dorsolateral in anterior setigers, gradually shifting to a mid-lateral location (Fig. 3C); noto- and neurochaetae arising from short, welt-like protuberances. Parapodia appear to emerge from posterior edge of each segment, just posterior to segmental constriction and anterior to narrow band of MG when stained.

Setae relatively short, inconspicuous along body, those of anterior 25 segments slender capillaries in a single row, with up to 15–20 per ramus of both noto- and neuropodia (20–30 per ramus in paratypes provided to him by Dr. Kirkegaard, as noted by Laubier 1966: 637), with fewer setae more posteriorly, reduced to 5–10 per ramus in some paratypes, further reduced to 2–4 setae in far posterior segments. Capillaries relatively short throughout, similar in length and shape within a fascicle, broader basally, abruptly tapering but not aristate distally; notosetae longer than neurosetae, with fine denticles in broad basal part, these not continuing or at least not visible in thin apical extension; most neurosetae shorter than notosetae but similar with fine denticles along one edge of shaft (Fig. 3E); setae arranged within fascicles such that denticles of notosetae directed ventrally and those of neurosetae directed dorsally, *vis-à-vis* (Fig. 4A–C). In posterior abdominal setigers, ventral most 2–3 neurosetae thicker, with very broad base and thicker denticles similar to those described by Kirkegaard (1959: Fig. 3). Far posterior setigers with denticles generally thicker than those of anterior and middle abdominal setigers (Fig. 4B–C). First appearance of denticulated setae difficult to detect without dissecting numerous segments, but present by at least setigers 15–20 in paratypes.

Methyl Green stain. A left lateral diagram of the holotype depicts the general pattern of MG staining (Fig. 3C): tip of prostomium staining dark green with rest of prostomium and most of peristomium evenly speckled light green except for darker anterior area between nuchal organs. Anterior segments with ventral diffuse greenish area, but stain mainly limited to anterior dorsum and dorsolateral areas of thorax (Fig. 3C); rest of body with stain dorsally concentrated in segmental constrictions, ending just behind parapodia; ventrally with narrow, elongate, diffuse mid-ventral spot on each segment, fading out on posterior segments. Dorsal channel between parapodia does not stain. Same general pattern present on paratypes, but not as prominent.

Remarks. According to a summary of the type material of *Cirratulus dorsobranchialis* provided to me by the late Dr. Mary E. Petersen (letter dated 14 July 1985) there were originally 13 paratypes of *C. dorsobranchialis* designated by Dr. Kirkegaard in addition to the holotype. Of these, three paratypes were loaned to Dr. L. Laubier and were commented on by him (Laubier 1966); however, the paratypes were not returned and Dr. Laubier subsequently informed Dr. Kirkegaard that they were lost. In addition, three paratypes were loaned to Dr. A. Eliason and these were also lost. Of the remaining seven paratypes, Dr. Petersen sent three to me for evaluation (Blake 1991); these were returned to Dr. Petersen. While working on cirratulids for the California Taxonomic Atlas, I had occasion to review the notes and sketches of the paratypes examined earlier and asked Dr. Petersen to check a few details, which she kindly provided in April 1994. This reexamination resulted in the conclusion that the synonymies proposed in Blake (1991) were not correct; comments to this effect were stated in (Blake 1996: 318). In September 1997 during a short visit with Dr. Petersen in Copenhagen, I was able to examine the holotype and other specimens of *C. dorsobranchialis* from Dr. Kirkegaard's collection and prepared some additional notes and sketches. As part of a review of Dr. Petersen's research materials following her death, I discovered her own notes and sketches of the *C. dorsobranchialis* types, which supported my own conclusions. Figure 4A–E is based on Dr. Petersen's pencil sketches of selected paratypes and prepared slides of parapodia.

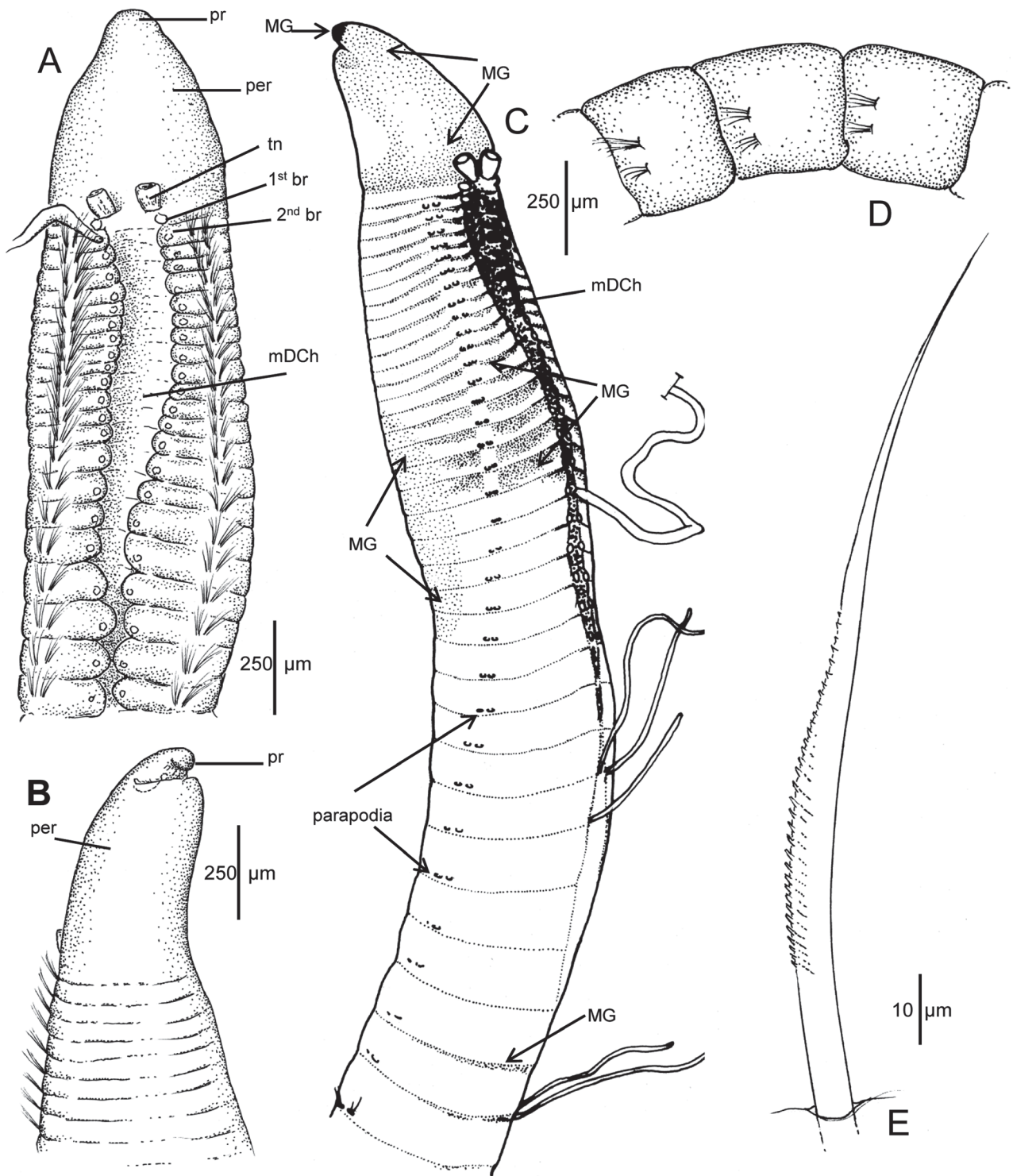


FIGURE 3. *Kirkegaardia dorsobranchialis* (Kirkegaard, 1959): A, anterior end, dorsal view; B, same, ventral view; C, same left lateral view, showing Methyl Green staining patterns; D, middle abdominal segments, right lateral view; E, neuroseta middle abdominal segment. A–D, holotype (ZMUC-POL-241); E, paratype (ZMUC-POL-242).

The type specimens described here differ in several important aspects from the description by Kirkegaard (1959). Most importantly, Kirkegaard (1959: Fig. 2) illustrated a worm with 2–3 anterior achaetous annulations; these were not mentioned in the text. The peristomium of the holotype and paratypes had only a smooth surface with no obvious annulations apparent, although faint lines were visible on one paratype (Fig. 4E). The obvious annulations in Kirkegaard (1959: Fig. 2) might have been due to misinterpretation by the artist who illustrated the

specimens for Dr. Kirkegaard. On the same figure, some branchiae are illustrated with inflated tips; these also do not occur on the types examined and were also noted to be absent on the paratypes examined by Laubier (1966); Day (1961) also indicated that such branchiae were not present on the South African specimens he examined.

The short, strongly dentate setae illustrated by Kirkegaard (1959: Fig. 3) were not observed during my initial study of the type material and were not observed by Laubier (1966) in the paratypes he examined and were not observed in specimens identified as *Tharyx dorsobranchialis* by Day (1961, 1967); instead, only finely serrated setae were observed. It was not until individual parapodia from different parts of the body of paratypes were carefully examined that setae with conspicuous denticles were observed at 400x (Fig. 4A–C). Most of the denticulated setae along the body have only numerous fine serrations along the shaft (Fig. 3E) and for the longest and thinnest setae, they were only barely apparent at 400x.

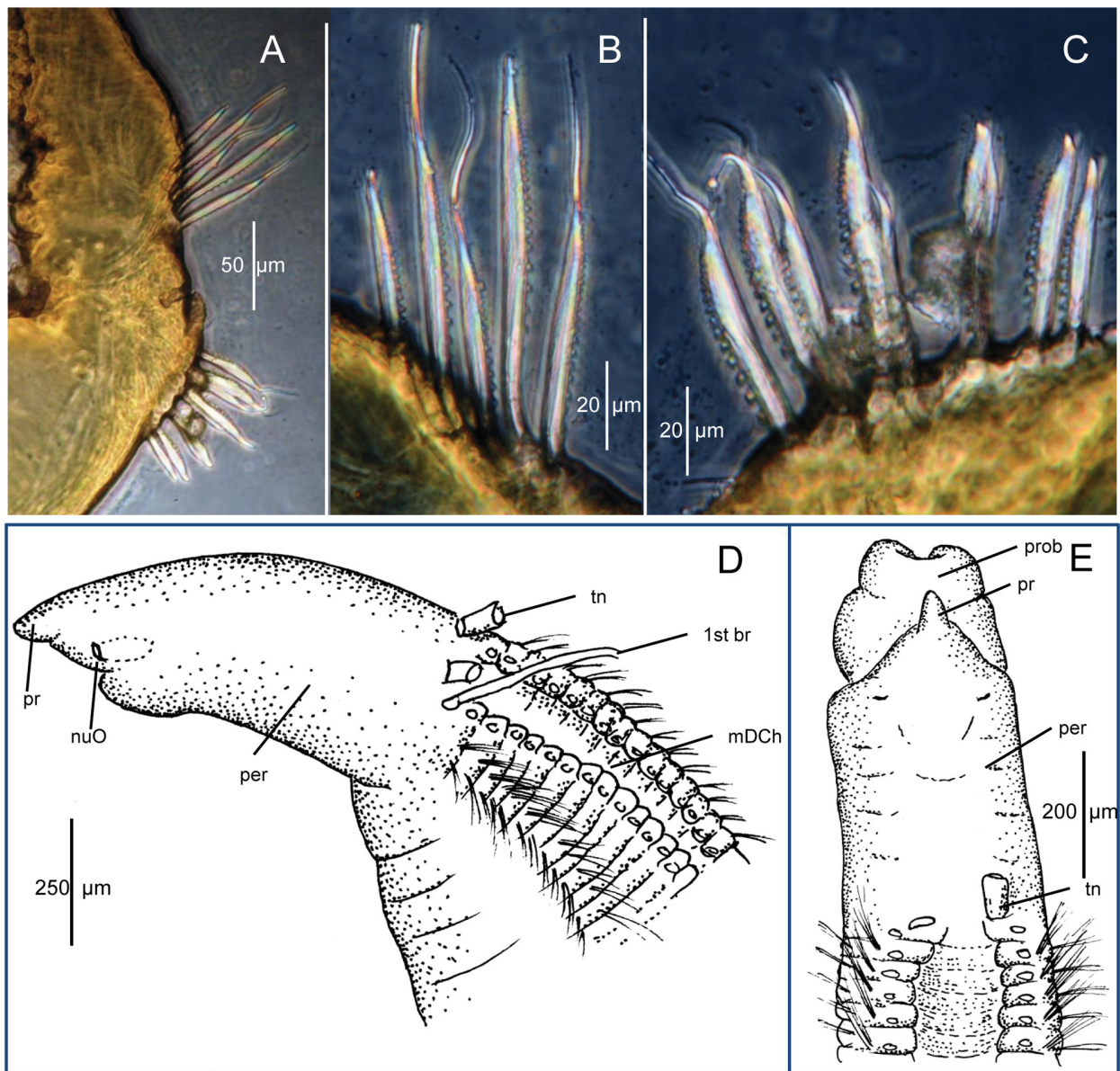


FIGURE 4. *Kirkegaardia dorsobranchialis* (Kirkegaard, 1959): A, posterior parapodium, left anterior view; B, notosetae from same; C, neurosetae from same; D, anterior end, left dorsolateral view; E, anterior end, dorsal view. A–C, paratype (ZMUC-POL-242); D–E, paratypes (ZMUC-POL-243). A–C were photographed from slides prepared by the late Mary E. Petersen; D–E, based on pencil sketches originally prepared by Mary E. Petersen.

The most conspicuous difference between *Kirkegaardia dorsobranchialis* and *K. heterochaeta* noted by Laubier (1966) was the presence of distinct peristomial rings in the first species and none in the second. However, the peristomial rings illustrated by Kirkegaard (1959: Fig. 2) are not present on the holotype and only vague rings

were observed on one of the paratypes of *K. dorsobranchialis*. Thus, other characters are required in order to distinguish between the two species.

One obvious difference is that *K. dorsobranchialis* has a much shorter peristomium than *K. heterochaeta*. In *K. heterochaeta* the long narrow head region (prostomium + peristomium) is as long as the first 8–10 setigers and has a length to width ratio of ca. 2.2:1 whereas in *K. dorsobranchialis* the ratio of length to width is no more than 1.5:1 in the paratypes and only 1.1:1 in the holotype. In addition, specimens of *K. heterochaeta* examined here have a raised mid-dorsal ridge within the dorsal channel that is not present in *K. dorsobranchialis*.

The most conspicuous difference between the two species, however, is the MG staining pattern. *Kirkegaardia heterochaeta* has a prominent oval green patch on the dorsum of the second half of the peristomium prior to the origin of dorsal tentacles and a spectacular dark blue pattern concentrated on the thorax as stripes that begin mid-dorsally and continue down each side with the most intense stain on the venter of the thoracic region. In contrast, the staining pattern of *K. dorsobranchialis* is less intense, with the tip of the pre-setigerous region darkly stained and the rest of the prostomium and peristomium evenly covered with light speckles. The thoracic segments have a mid-ventral greenish area, but not the intense blue of *K. heterochaeta*, and stripes are not formed. A narrow, elongate, diffuse mid-ventral spot is present on abdominal segments of both species.

Recent records of *K. dorsobranchialis* from the Mediterranean by Çinar (2005) and others have not been confirmed. Given the large number of species identified as part of this study from worldwide locations and the differences between the present description of the type material and the original description by Kirkegaard (1959), it is likely that non-African records of *K. dorsobranchialis* belong to other species.

Among other species of *Kirkegaardia* reviewed in this study, *K. dorsobranchialis* is closest morphologically to *K. carinata* n. sp. from deep-water off northern California, *K. chilensis* n. sp. from offshore Chile, and *K. cryptica* (Blake, 1996) from southern California shelf and slope depths. All of these species have an entirely smooth peristomium without either ridges or annular rings. Of these, *K. dorsobranchialis* and *K. cryptica* have a smooth mid-dorsal channel; whereas, *K. carinata* n. sp. and *K. chilensis* n. sp. have a prominent ridge within the channel. *K. cryptica* differs most noticeably from *K. dorsobranchialis* in (1) having a longer pre-setigerous area of 1.9:1 length-to-width ratio instead of up to 1.5:1, (2) having few sharply pointed, widely spaced denticles on the neurosetae instead of numerous larger denticles that are tightly spaced, and (3) several differences in the MG staining patterns.

Biology. The species is recorded from sand and mud in False Bay, South Africa. Other records do not have any sediment data. Short-headed sperm were recorded for this species by Petersen (1999), based on the type collection from Angola, Bay off Lobito in 27 m; presence of sperm was also confirmed as part of my examination of the holotype.

Distribution. West Africa from off Sierra Leone to Angola 27–100 m; South Africa, coastal waters and embayments, 20–105 m; also recorded from the eastern Mediterranean Sea in shallow water.

***Kirkegaardia annulosa* (Hartman, 1965), new combination**

Figures 5–6

Tharyx annulosus Hartman, 1965: 167–168, pl. 34 (In part); Hartman & Fauchald 1971: 111; Maciolek *et al.* 1987: Appendix D-2.

Tharyx annulosa: Laubier 1966: 633–637.

Not *Caulleriella annulosa* Banse & Hobson, 1968: 31, fig. 7a (= *Tharyx kirkegaardi* Blake, 1991).

Monticellina dorsobranchialis: Blake 1991: 24–26 (In part).

Material examined. **Western North Atlantic, upper end of Atlantis Canyon**, R/V *Atlantis* Sta. Slope 4, 39°56'30"N, 70°38'54"W, 400 m, coll. 28 Aug 1962, **holotype** and 75 **paratypes** (LACM-AHF Poly 0578–9).—**Off Georges Bank**, continental slope south Cape Cod, US North Atlantic ACSAR Program, Cruise 5, R/V *Cape Hatteras*, Sta. 12, replicate 2, 06 May 1986, 39°54.27'N, 70°55.17'W, 548 m, coll. G. Hampson, WHOI, Chief Scientist, 90 specimens (USNM 1407158); Cruise 6, R/V *Cape Hatteras*, Sta. 12, replicate 1, 30 July 1986, 39°54.24'N, 70°55.09'W, 563 m, coll. G. Hampson, WHOI, Chief Scientist, 110 specimens (USNM 1407159); Cruise 6, R/V *Cape Hatteras*, Sta. 12, replicate 3, 30 July 1986, 39°54.24'N, 70°55.09'W, 563 m, coll. G. Hampson, WHOI, Chief Scientist, 42 specimens (USNM 1407160).

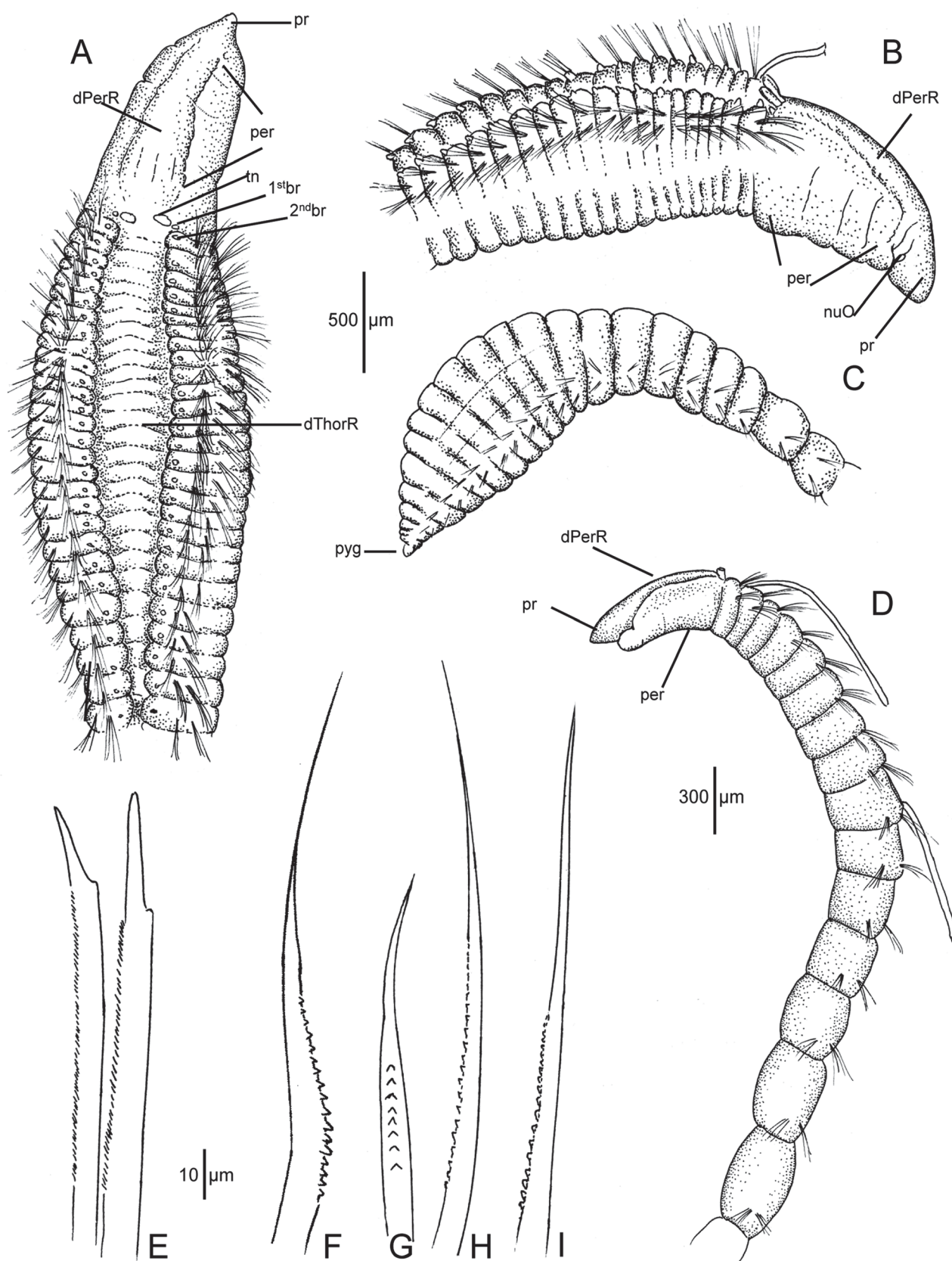


FIGURE 5. *Kirkegaardia annulosa* (Hartman, 1965): A, anterior end, dorsal view; B, anterior end, right lateral view; C, posterior end, right lateral view; D, anterior end of holotype in left lateral view; E, spinous neurosetae from a middle abdominal segment; F–G, denticulated neurosetae from posterior abdominal segments; H–I, denticulated notosetae from middle abdominal segments. A–C, E–I paratype (LACM-AHF Poly 0579); D, holotype (LACM-AHF Poly 0578).

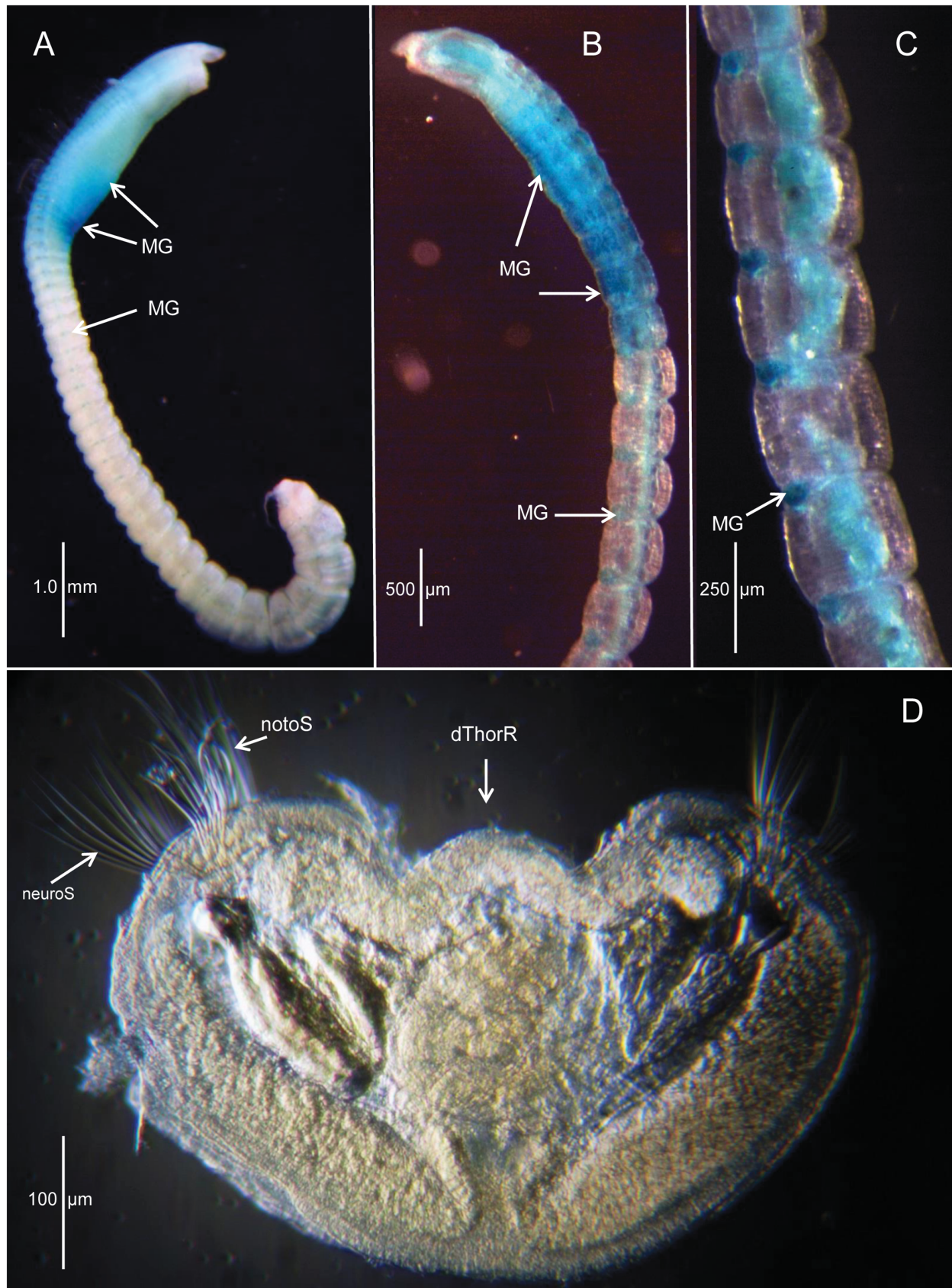


FIGURE 6. *Kirkegaardia annulosa* (Hartman, 1965), photomicrographs of specimens from off Georges Bank showing Methyl Green staining pattern: A, right anterior view; B, left anterior view of another specimen; C, detail of abdominal region of same; D, Cross section through thoracic region of a specimen from off Georges Bank. (USNM 140758).

Description. Holotype elongate, narrow, in two pieces. Anterior fragment about 16 mm long, 0.3 mm wide for about 55 setigers; thoracic region with about 12 narrow segments before changing to moniliform shape, segments dorsoventrally flattened, about 3.5x wider than long, not crowded (Fig. 5D). Posterior fragment about 4.5 mm long for about 45 setigers, thus entire holotype 20.5 mm long, 0.7 mm wide, for about 100 setigers. Color in alcohol light tan. Specimens from ACSAR station 12 off Georges Bank similar in appearance and size to holotype. One typical complete specimen with 12 thoracic setigers, long narrow abdominal region with 65 setigers and a posterior region of 11–12 setigers for a total of about 90 setigers measuring 16.65 mm long and 0.5 mm wide across thorax. Specimens from ACSAR Sta. 11 larger, similar in size to paratypes.

Paratypes larger, more robust than holotype, none complete; longest incomplete paratypes with 20–25 thoracic setigers and 30–65 abdominal setigers; posterior fragments with 45–50 setigers. Thoracic region expanded laterally, flattened dorsally, rounded ventrally, with crowded segments each about 15x wider than long (Fig. 5A–B). Thoracic region of two paratypes 0.75 mm wide and 0.45 mm dorsal to ventral (Fig. 5A–B); subsequent segments becoming longer, oval to moniliform in shape continuing over a long abdominal region; far posterior segments producing an inflated region, ventrally flattened or grooved, with numerous narrow segments tapering to simple pygidium with terminal anus and conical ventral lobe (Fig. 5C).

Pre-setigerous region twice as long as wide, as long as first six setigers of holotype and 15 setigers of largest paratypes (0.75 mm). Prostomium triangular, tapering to narrow, rounded anterior margin (Fig. 5A–B, D), of same shape and proportions as shown by Hartman, without eyes or any detectable pigment; nuchal organs at posterolateral border of prostomium (Fig. 5B), sometimes staining internally with Shirlastain A. Peristomium elongate, with one anterior lateral annular ring apparent on holotype and specimens from ACSAR Station 12; larger paratypes with at least three thin, weakly visible lateral grooves apparent when stained with Shirlastain A, producing four annular rings visible on lateral sides (Fig. 5A–B); long dorsal crest extending from prostomium to end of pre-setigerous area on all specimens, well developed and obvious on paratypes and specimens from ACSAR samples (Fig. 5A–B). Paired dorsal tentacles arise on posterior margin of peristomium; first pair of branchiae lateral to dorsal tentacles, also on peristomium (Fig. 5A–B, D); second pair of branchiae on setiger 1.

Thoracic region with parapodia shifted dorsally over midline, producing a prominent mid-dorsal groove containing a low mid-dorsal ridge (Figs. 5A, 6D). Opening of mid-dorsal groove narrowing and closing at end of thoracic region (Fig. 5A). Branchiae dorsal to notopodia on edge of mid-dorsal groove. Parapodia shifted laterally in abdominal segments (Fig. 5C).

Parapodia with only low setal tori or mounds from which setae project; notosetae typically longer than neurosetae, continuing to posterior segments; long natatory notosetae not observed. Notosetae of paratypes numbering 8–12 per fascicle in thoracic region, reduced to 5–8 in middle beaded segments; neurosetae numbering 10–12 per fascicle in thoracic segments, reduced to 5–8 in middle and posterior abdominal segments. Capillary setae of thoracic region to middle abdominal segments at about setiger 45 with smooth or only finely serrate edges; denticulate capillaries first evident with 400x from about setiger 50, continuing to far posterior segments. Denticles relatively inconspicuous, limited mainly to thickest part of shaft, not observed along tapering, narrow apex; denticles of neurosetae (Fig. 5F–G) more prominent than those of notosetae (Fig. 5H–I). Heavily serrated or denticulated setae as illustrated in original description not observed. Unusual spinous or spike-like setae observed in middle abdominal neuropodia of a few paratypes; each with finely serrated edge of fibrils along shaft tapering to sharp point; some with a subapical spur (Fig. 5E); these possibly transitional between non-serrated capillaries and those with distinct denticles.

Posteriormost segments narrow, tapering to pygidium bearing short lobe ventral to anal opening (Fig. 5C).

Methyl Green stain. Methyl Green imparts a distinct pattern. The entire pre-setigerous region stains only lightly or not at all. The posterior half of the thoracic region stains distinctly with several broad stripes forming a dark blue patch on the venter, most obvious on last 3–6 thoracic setigers (Figs. 6A–B); these stripes extend dorsally up and over the parapodia becoming narrow and dorsolateral on individual segments. There are weak narrow transverse lines of stain also evident on the sunken dorsal surface of the thorax. Ventrally, a narrow line of stain extends posteriorly from the thoracic region along the narrow mid-ventral line; this is broken into separate spots on some specimens. Laterally, there are inter-segmental lateral spots or patches on most abdominal segments (Fig. 6B–C); these are distinctive for this species.

Remarks. *Kirkegaardia annulosa* is an elongate thread-like species that belongs to the group of species in which the thoracic parapodia are shifted upwards so that the dorsum becomes restricted to a narrow area between the parapodia; a narrow dorsal groove is thus produced that in *K. annulosa* also carries a mid-dorsal crest.

Branchiae are inserted along the elevated sides and sometimes project into the dorsal groove. The branchiae remain in a mid-dorsal position in the abdominal region while the parapodia shift to a more lateral position. This arrangement also occurs to varying degrees in *K. dorsobranchialis*, *K. heterochaeta*, and several other species and is unique among cirratulids. *K. annulosa* was among the first species to be described from North America with this type of thoracic region (Hartman 1965); it has not been redescribed since the original report.

The types collected from Atlantis Canyon off New England and specimens from the ACSAR stations on the New England slope examined in this study occurred relatively close to one another both geographically and with depth. This large collection revealed that several aspects of the original description by Hartman (1965) differed from what is presented in this redescription, in part because the holotype is relatively small compared to the numerous paratypes, but also because the use of stains such as Shirlastain A and Methyl Green emphasize fine details not evident without these treatments.

The pre-setigerous area including the prostomium and peristomium was described and illustrated as long, cylindrical, and smooth (Hartman 1965). While this is generally true of the small holotype, one partial lateral annular groove was evident when stained with Shirlastain A, thus producing one narrow annular ring posterior to the prostomium and one longer one on the peristomium; this is the same arrangement found in the ACSAR specimens. However, in the larger paratypes 3–4 distinct annular rings produced by lateral grooves along the peristomium were evident when stained; further, a distinct dorsal crest that extends from the prostomium posteriorly to near the dorsal tentacles at the posterior margin was observed in all specimens. The ACSAR specimens were similar in size and appearance to the holotype. The crowded thoracic segments were said to transition to beaded abdominal segments by setiger 10 (Hartman 1965). However, the thoracic region of the holotype and the ACSAR specimens consists of only about 12 setigers; whereas, the larger paratypes typically have 20–25 crowded setigers before the more elongate abdominal segments begin.

Hartman (1965: Plate 34d–e) illustrated the denticulate capillaries as having prominent denticles along the expanded shaft. In this study, denticles were visible at 400x, but they were sparse and relatively inconspicuous on several specimens examined. The unusual spike-like spinous setae that occur in a few anterior abdominal neuropodia of some paratypes were not reported in the original description. Additionally, the first pair of branchiae were reported as occurring on setiger 1 when actually they occur lateral and slightly posterior to the dorsal tentacles on the peristomium; the second pair of branchiae occur on setiger 1. This is the same arrangement as in *K. heterochaeta* and *K. dorsobranchialis* and many other species reported in this paper (See Table 1).

Among species of *Kirkegaardia* reported in the present study, *K. annulosa* is closest morphologically to *K. cristata* **n. sp.** from shallow waters of the Puget Sound in the NE Pacific, *K. kladara* **n. sp.** from the continental slope off North Carolina, and *K. hampsoni* **n. sp.** from continental shelf depths along the U.S. Atlantic coast. All four species have a mid-dorsal ridge along the entire length of the peristomium and another ridge within the mid-dorsal thoracic channel. In *K. annulosa*, however, the mid-thoracic ridge is formed by the entire surface of the mid-dorsal channel being elevated, whereas the other three species have a separate narrow ridge arising from the middle of the channel. *K. kladara* **n. sp.** differs from *K. annulosa* and the others in this group by having the first pair of branchiae arising from setiger 1 instead of lateral to the dorsal tentacles on the peristomium. *K. annulosa* and *K. hampsoni* **n. sp.** both have 0–2 annular rings on the peristomium and a length-width ratio for the pre-setigerous area of 2:1, whereas *K. cristata* **n. sp.** has four annular rings on the peristomium and a length to width ratio of 1.6:1 on the pre-setigerous area.

The MG staining pattern can also be used to separate of *K. annulosa* and *K. hampsoni* **n. sp.** The broad ventral stripes that occur in the posterior segments of the thoracic region of *K. annulosa* give way to prominent lateral intersegmental spots that occur on at least 30–40 abdominal segments. These lateral abdominal spots alone can be used to identify the species among other cirratulids in benthic samples from the U.S. Atlantic slope. Similar spots occur on *K. carinata* **n. sp.** from deep continental slope sediments off northern California (see below). However, *K. carinata* **n. sp.** differs from *K. annulosa* in peristomial morphology and other MG staining reactions. *K. hampsoni* **n. sp.** has prominent dorsal and lateral stain retained on the peristomium, whereas peristomial staining on *K. annulosa* is weak and de-stains rapidly.

Kirkegaardia annulosa and *K. hampsoni* **n. sp.** are thus the two species of the genus most closely related to one another morphologically and locally appear to be a sibling species pair with one species, *K. hampsoni* **n. sp.**, occurring in nearshore and outer continental shelf depths at about 30–150 m and the other species, *K. annulosa*, an upper continental shelf species occurring at about 250–550 m. *K. annulosa* was also recorded by Hartman (1965) from deeper slope depths, but these records have not been confirmed.

The 75 paratypes of *Kirkegaardia annulosa* include numerous specimens of other cirratulids including *Tharyx kirkegaardi* Blake, 1991 and at least two species of *Aphelochaeta*. The record of *Tharyx annulosus* by Day (1973) from off Beaufort, NC, in 80–200 m is most likely *K. baptisteae*, which has been identified from shelf depths off Cape Lookout, NC, in the ACSAR program; *K. annulosa* was not collected in those surveys.

Biology. As part of the North Atlantic ACSAR program, *K. annulosa* (identified as *Tharyx dorsobranchialis* and *T. annulosus*) was the dominant benthic invertebrate at three 550 m stations sampled as part of the 2-year program. At station 12, the species was the single most abundant species out of 308 species identified as part of five surveys made between November 1984 and July 1986 (Maciolek *et al.* 1987). Examination of the station data indicates that *K. annulosa* was present but not among the dominant species at the shallower 250-m station and was absent or rare at deeper stations (>1200 m) on the same transects. Thus, based on the type collection and the ACSAR results, the species appears to be an important component of the upper slope benthic community at depths of 250–550 m.

Most specimens from North Atlantic ACSAR Sta. 12 were covered with closely adhering tube fragments that were encrusted with fine sand grains. Some specimens from the same station collected in May 1986 were gravid with tightly packed large yolky eggs measuring 146–195 μm in diameter (average = 172.6 μm); each egg had an obvious germinal vesicle.

Distribution. Western North Atlantic, upper continental slope depths 250–550 m; other reported collections in deeper slope and abyssal depths to 4540 m likely belong to other species.

***Kirkegaardia baptisteae* (Blake, 1991) new combination**

Figures 7–8

Tharyx annulosus: ?Day 1973: 82; Maciolek-Blake *et al.* 1985:18–76; Blake & Baptiste 1985: 140–178; Maciolek & Grassle 1987: 306. Not Hartman, 1965.

Tharyx sp. 2: Blake *et al.* 1987: 8–85, fig. 15; Maciolek *et al.* 1987: Appendix D-2, 1987b: Appendix D-2; Blake & Grassle 1994: 855.

Monticellina baptisteae Blake, 1991: 24–26, Fig. 4; Hilbig 1994: 941; Hilbig & Blake 2000 147–164.

Material examined. Western North Atlantic, Off Cape Lookout, North Carolina, U.S. South Atlantic ACSAR Program Cruise 1, R/V *Columbus Iselin* Sta. 1, replicate 1, 11 November 1983, 34°16.36'N, 75°45.50'W, 640 m, coll. J.A. Blake, Chief Scientist, 22 specimens (USNM 1407157).—Off New England, Georges Bank, BIMP, Cruise M-3, R/V *Endeavor*, Sta. 5-8, February 1982, 40°40.1'N, 67°46.1'W, 80 m, coll. G. Hampson, WHOI, Chief Scientist, 9 specimens (USNM 1407153); Sta. 5-14, February 1982, 40°39.5'N, 67°44.7'W, 86 m, coll. G. Hampson, WHOI, Chief Scientist, 9 specimens (USNM 1407154); Sta. 5-16, February 1982, 40°40.6'N, 67°46.1'W, 78 m, coll. G. Hampson, WHOI, Chief Scientist, 14 specimens (USNM 1407155); Cruise M-6, R/V *Oceanus*, Sta. 12, 26 Nov 1982, 40°22.2'N, 68°29.8'W, 103 m, coll. G. Hampson, WHOI, Chief Scientist, 4 specimens (01407156).—Off Georges Bank, Lydonia Canyon, US North Atlantic ACSAR Program, Cruise 1, R/V *Cape Hatteras*, Sta. 7, replicate 3, 10 Nov. 1984, 40°27.52'N, 67°40.36'W, 560 m, coll. G. Hampson, WHOI, Chief Scientist, 325 specimens (USNM 1407152).—Massachusetts Bay, MWRA long-term monitoring program, 2007 survey, R/V *Aquamonitor*, Sta. FF-01A, Rep. 2, 30 Jul 2007, coll. P. Neubert, 42.564°N, 70.676°W, 35.8 m, 15 specimens (MCZ 135292).

Description. An elongate, threadlike species, complete typical specimen from off Georges Bank 14.5 mm long, 0.4 mm wide with 155 setigerous segments. Thoracic region with 10–14 setigers depending upon size; each thoracic segment narrow, 5x wider than long, followed by longer abdominal segments about 2x as wide as long, none appearing moniliform or beadlike; far posterior segments again becoming narrow and crowded producing expanded pre-pygidial region rounded dorsally (Fig. 7C) and flattened ventrally with a weak mid-ventral groove or channel (Fig. 8C). Pygidium a rounded segment with narrow terminal lobe (Figs. 7C, 8C). Color in alcohol light tan with venter of thoracic region sometimes with brownish caste evident on individual segments.

Pre-setigerous region relatively short, about 1.5x as long as wide. Prostomium triangular, tapering to narrow apex (Figs. 7A–B; 8A, D); eyes absent; nuchal organs as narrow slits on posterior lateral margins (Fig. 7B). Peristomium incised with two distinct lateral grooves producing three annular rings (Figs. 7A–B, 8B), but these not extending across dorsum. Dorsal tentacles arising on posterior border of peristomium extending between parapodia of setiger 1 (Fig. 7A; 8D). First pair of branchiae lateral to dorsal tentacles on peristomium (Fig. 7A–B); second

pair of branchiae on posterior medial border of setiger 1, subsequent thoracic segments with branchiae in similar location (Fig. 7A–B).

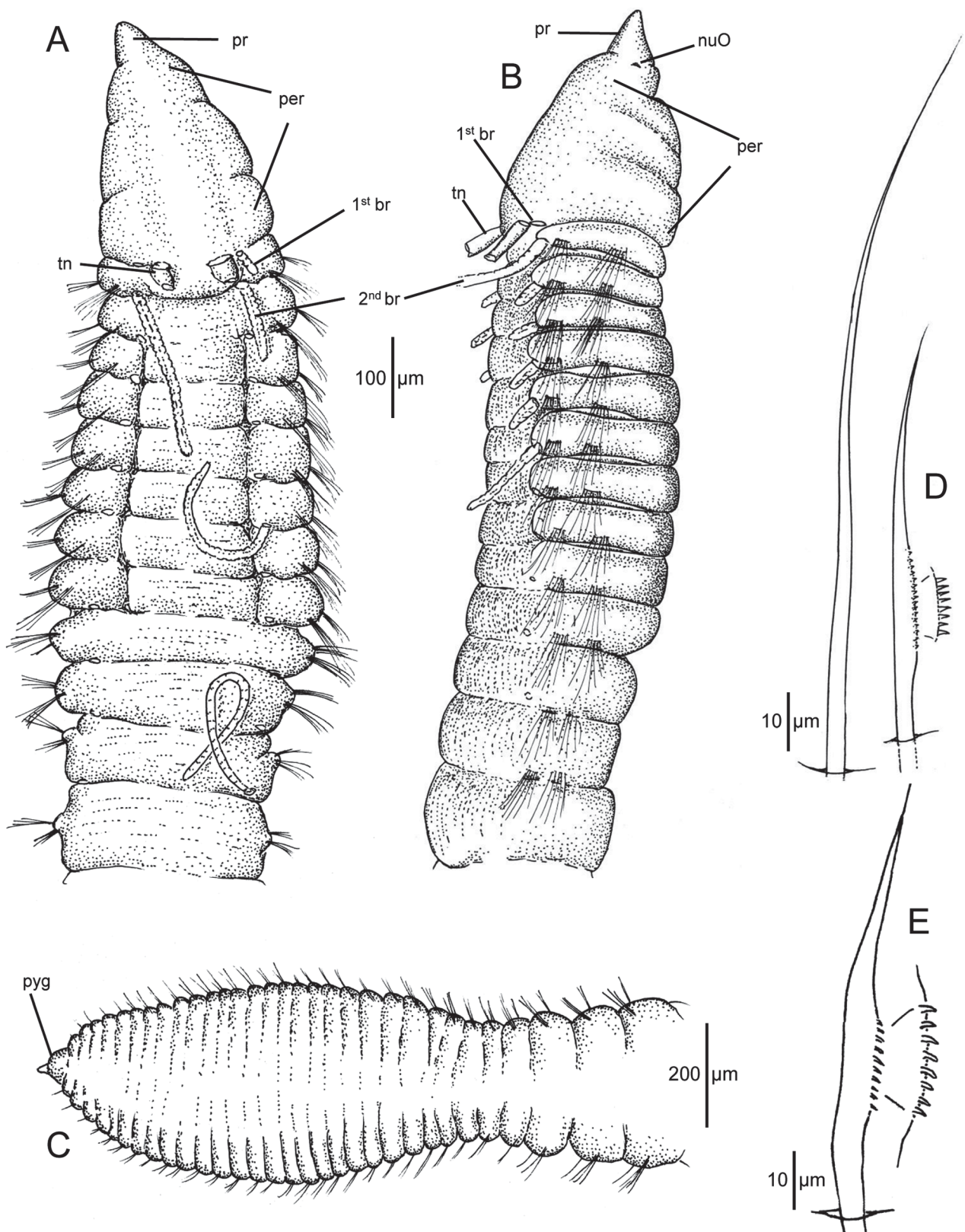


FIGURE 7. *Kirkegaardia baptisteae* (Blake, 1991): A, anterior end, dorsal view; B, anterior end in right lateral view; C, posterior end, dorsal view; D, abdominal notosetae; E, abdominal neuroseta. (USNM 1407152).

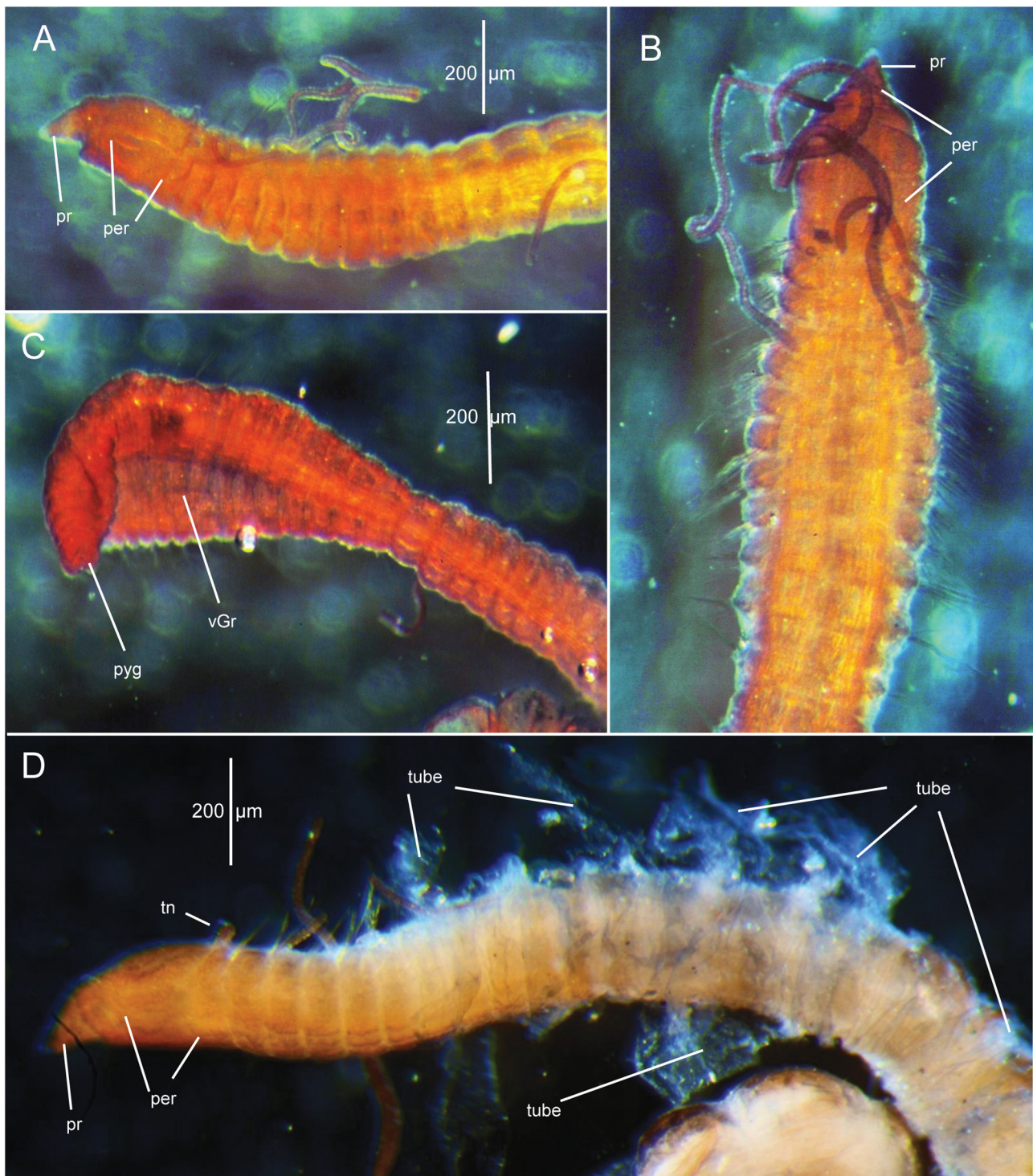


FIGURE 8. *Kirkegaardia baptisteae* (Blake, 1991), photomicrographs of specimens from off Georges Bank, Lydonia Canyon: A, anterior end in left lateral view; B, anterior end in dorsal view; C, posterior end, ventral view; D, anterior end, left lateral view of a specimen with remnants of a tattered tube. (USNM 1407152). Stained with Shirlastain A.

Thoracic region with parapodia forming lateral shoulders, but not elevated and shifted dorsally over midline as in related species; dorsal surface broadly elevated above parapodia, but with each segmental groove continuous across dorsum (Fig. 7A–B). Branchiae dorsal to notopodia; parapodia with only low tori or mounds from which setae project; notosetae typically longer than neurosetae; long natatory notosetae not observed. Notosetae numbering 10–14 per fascicle in thoracic region, reduced to 5–6 in abdominal segments; neurosetae numbering 8–10 per fascicle in thoracic segments, reduced to 5–6 in middle and posterior abdominal segments. Capillary setae of thoracic segments long, narrow, with no visible serrations or denticles along margin; from anterior abdominal

segments and along most of abdominal region, some notosetae and all neurosetae with distinct denticles along cutting edge. Notosetae of abdominal segments include 2–3 long thin, smooth capillaries and 1–2 short, thicker capillaries with fine denticles (Fig. 7D). Neurosetae of abdominal segments all short, thick denticulated capillaries (Fig. 7E). Setae arranged in fascicles such that denticulated edge of notosetae directed ventrally while same edge of neurosetae directed dorsally, *vis-à-vis*. Denticles visible on both noto- and neurosetae at 400x but details of fine denticles not apparent until 1000x magnification.

Methyl Green stain. There is no MG staining pattern of any kind on *K. baptisteae*: the stain disappears entirely in clean alcohol.

Remarks. This redescription of *K. baptisteae* provides additional details and corrects some errors in the original description (Blake 1991). In the original account the peristomium was described as smooth and without annulations. This is not correct: there are actually two lateral grooves variably developed and best seen with SEM or when stained with Shirlastain A. These grooves do not extend over the dorsum, but two or three annular rings are readily apparent laterally. The dorsal tentacles arise at the level of setiger 1 but are on a short extension of the posterior peristomium onto the dorsum between the first two parapodia. The first pair of branchiae actually occur lateral to the dorsal tentacles on the peristomium; these were not reported in the original description and again the scars or stubs of these are best observed with SEM or when stained with Shirlastain A. The second pair of branchiae occur on the posterior border of setiger 1. The far posterior segments containing the pygidium are more expanded and flattened ventrally than reported and illustrated by Blake (1991).

Among the known species of *Kirkegaardia* including those described in this paper, *K. baptisteae* is most closely related to *K. dutchae* **n. sp.** from the Puget Sound in the northeastern Pacific. The two species differ in that *K. baptisteae* has ventral thoracic glands that are naturally light tan in color and do not produce a MG staining pattern of any kind, with the stain disappearing entirely in clean alcohol; however, these glands may retain the pink coloration from Rose Bengal for a time after storage. In contrast, the same glands of *K. dutchae* **n. sp.** display a distinct MG pattern to the venter of the thoracic region after differentiation. Other differences include details of the denticulated capillaries of the neurosetae and the lack of denticulated notosetae in *K. dutchae* **n. sp.** that are present in *K. baptisteae*. In addition, the first pair of branchiae of *K. baptisteae* occur lateral to the dorsal tentacles on the posterior edge of the peristomium; in *K. dutchae* **n. sp.** the first pair of branchiae are on the anterior margin of setiger 1 and the second pair are on the posterior margin of the same setiger resulting in two pairs of branchiae originating from the first setigerous segment.

Biology. *Kirkegaardia baptisteae* is one of the most common and widespread species of Cirratulidae along the U.S. Atlantic coast, ranging from the Canadian-US border to off North Carolina in shelf and slope depths. The species is typically found in well-mixed fine sediments and is often among the dominant species in offshore benthic communities (Hilbig & Blake 2000). Specimens have been observed with weakly tattered tubes (Fig. 8D) through which branchiae may project. However, these tubes consist of light, thin-textured materials that are easily removed from the worm and are similar to those of *K. tessellata* from off California. They are not the more heavily textured tubes that characterize other species such as *K. neotessellata* **n. sp.**, which are difficult to remove and result in distortion of the enclosed worms upon preservation.

As part of the 3-year monitoring program on Georges Bank, Blake & Baptiste (1985) developed data on the reproduction and life history of several abundant polychaete species including *K. baptisteae*, which at the time was misidentified as *Tharyx annulosus*. At station 13 (ca. 70 m), the species appeared to produce gametes in the winter and spawn in the spring. Reproductive data included the presence of males in November (19.2%) and February (27.9%) and females in July (22.2%), November (42.3%) and February (32.6%). No gametes were observed in individuals collected in May. Size frequency data followed this sequence of reproductive data with the highest percentage of juveniles (6.6%) present in the July collections. A similar pattern was observed for *K. baptisteae* collected at Station 5-1 (ca. 84 m), except that some males and females were observed in samples collected in May. A distinct difference, however, was observed in the population structure. All collections at Station 5-1, which had higher sand content in the samples, included fewer specimens but larger individuals than those found at Station 13 which has muddier sediments.

Several specimens collected in November from ACSAR Sta. 7 in Lydonia Canyon off Georges Bank were sexually mature females with large yolky eggs that produced swollen segments that were nearly moniliform in shape. The eggs numbered 8–10 per segment and ranged in diameter from 189–256 μm in their longest dimension (average = 231.4 μm , 1 SD = 25.86). The large size of these eggs suggests direct development of embryos that are

most likely released in the tubes. The presence of large, mature eggs in November supports the data collected by Blake & Baptiste (1985) where the highest percentage of females was identified in November 1981 with the next highest in February 1982.

Distribution. New England to Cape Lookout, North Carolina, in shelf and upper slope depths, 30–640 m.

***Kirkegaardia carolina* new species**

Figures 9, 10A–C

Tharyx sp. 3: Blake *et al.* 1987: Appendix C-2; Hilbig 1994: 941.

Material examined. Western North Atlantic, off Cape Lookout, North Carolina, U.S. South Atlantic ACSAR Program Cruise 1, R/V *Columbus Iselin* Sta. 2, Rep. 1, 12 November 1983, 34°14.87'N, 75°43.79'W, 1013 m, coll. J.A. Blake, Chief Scientist, **holotype** (USNM 1407162); Sta. 1, Rep. 2, 11 November 1983, 34°16.36'N, 75°45.50'W, 640 m, coll. J.A. Blake, Chief Scientist, 3 **paratypes** (USNM 1407163).

Description. An elongate, threadlike, fragile species; holotype from Sta. 2 complete, broken into two parts, 9.4 mm long, 0.2 mm wide across thorax and 0.23 mm wide across middle abdominal segments for about 75 setigers; complete paratype (very fragile) from Sta. 1 complete, 7.3 mm long, 0.3 mm wide with about 65 setigers (Fig. 10A). Bodies of some paratypes partially covered by remnants of thin, transparent tattered tube (Fig. 10A–C). Color in alcohol, light tan with no pigment.

Pre-setigerous region about 1.7x as long as wide. Prostomium triangular, narrowing to rounded tip (Fig. 9A); eyes absent; nuchal organs not observed. Peristomium elongate, slightly wider than anterior setigers, about 1.3x as long as wide, extending posteriorly to between setiger 1; lateral grooves producing three annular rings; dorsal surface elevated with broad dorsal ridge (Fig. 9A). Dorsal tentacles arising on posterior part of peristomium; first pair of branchiae posterior to tentacles on setiger 1 at posterior margin of setiger 1, dorsal to notosetae (Fig. 9A). Subsequent branchiae in same position on following thoracic setigers.

Thoracic region with 8–10 setigerous segments, each about 3x as wide as long (Fig. 9A); thoracic parapodia not elevated, dorsal surface between parapodia continuous over dorsum; body without ventral groove or ridge. Abdominal segments weakly moniliform, increasing in length to about 2.5x as long as wide (Fig. 9B); far posterior segments becoming narrow again, wider than long, forming elongated, weakly expanded and dorsoventrally flattened posterior section terminating in pygidium with dorsal anus overlying a conical lobe (Fig. 9C).

Parapodia reduced to low mounds from which setae project; thoracic notosetae consisting of long simple capillaries throughout, numbering 6–8 per notopodium in thoracic setigers, reduced to 4–6 in abdominal segments; denticulated notosetae absent. Thoracic neurosetae 6–8 long simple capillaries, reduced to 4–6 per neuropodium in anterior abdominal segments, becoming shorter, wider basally, with minute denticles along one edge visible from 400–1000x; denticulated setae first present from setigers 15–20; denticles with short pointed teeth directed lateral to main axis of shaft (Fig. 9D).

Methyl Green stain. Tip of prostomium stains weakly followed by weak diffuse bands around peristomium; narrow intersegmental grooves of thoracic region retain stain; entire intestinal track absorbs stain, but de-stains rapidly.

Etymology. This species is named for its type locality off Cape Lookout, North Carolina.

Remarks. *Kirkegaardia carolina* **n. sp.** is a small, threadlike species that co-occurs at the shallower slope stations off Cape Lookout with two congeners including *K. baptisteae* and *K. kladara* **n. sp.** Of these, *K. carolina* **n. sp.** is most similar to the larger, more robust *K. baptisteae*. Both species have tessellated tubes and 2–3 peristomial annulae. However, *K. baptisteae* has distinct parapodial shoulders in the thoracic region between which is a broad elevated dorsal surface; in contrast, *K. carolina* **n. sp.** has no parapodial shoulders and the surface of the thoracic region is continuous across the dorsum. *K. carolina* **n. sp.** has a dorsal ridge along the peristomium, first branchiae on setiger 1, lacks denticulated notosetae, has no expansion of the thoracic segments on the venter, and has a narrow posterior end that is only weakly expanded. In contrast, *K. baptisteae* has no peristomial dorsal ridge, the first branchiae occur lateral to the dorsal tentacles on the peristomium, has denticulated notosetae, has expanded thoracic segments on the venter, and the posterior end is broadly expanded. Additionally, while *K. baptisteae* has no MG staining pattern of any kind, *K. carolina* **n. sp.** retains stain in the intersegmental grooves of the thoracic region.

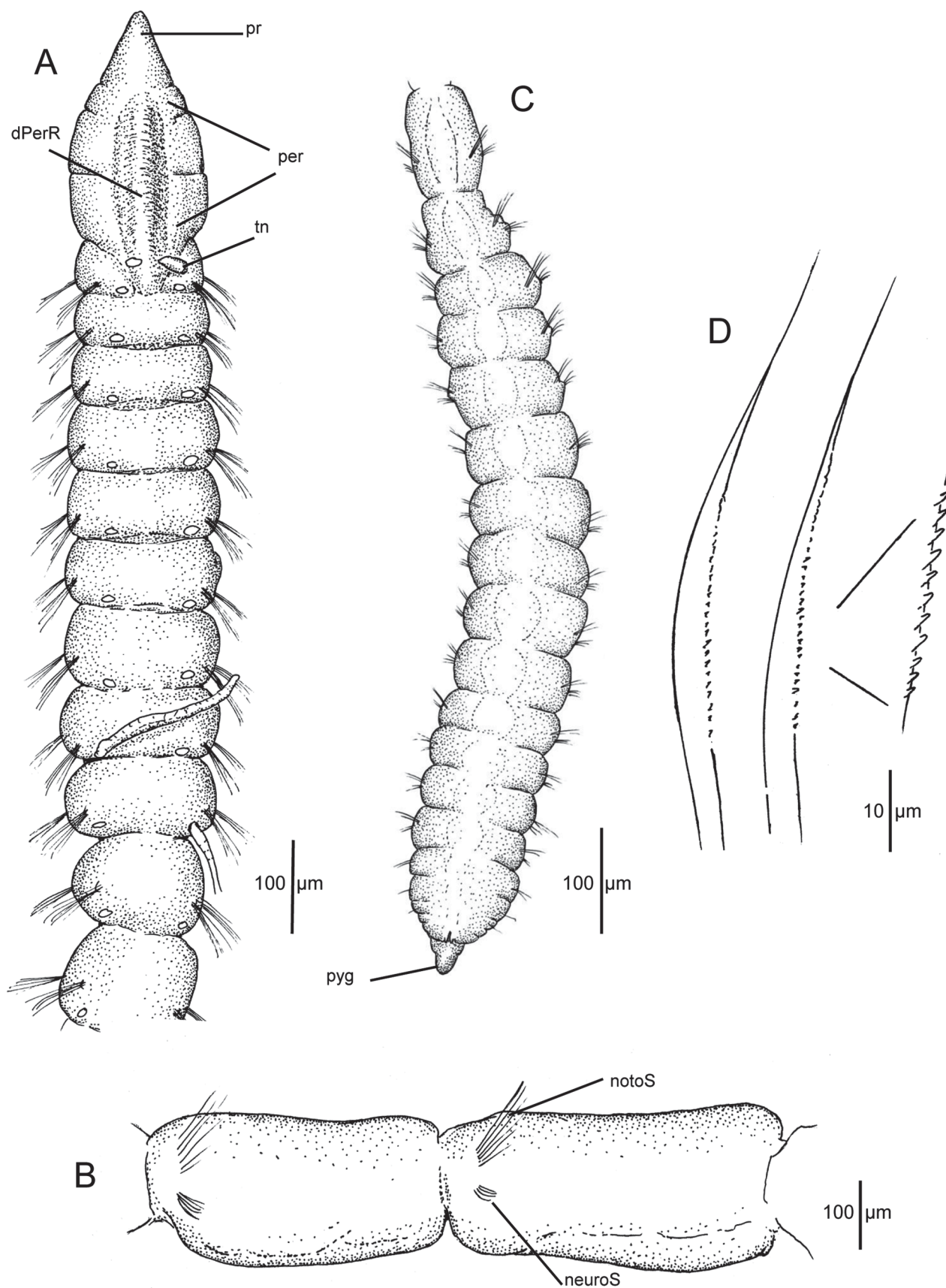


FIGURE 9. *Kirkegaardia carolina* n. sp.: A, anterior end, dorsal view; B, posterior abdominal segments, lateral view, dorsal side to the right; C, posterior end, left lateral view; D, abdominal denticulated neurosetae. (USNM 1407162).

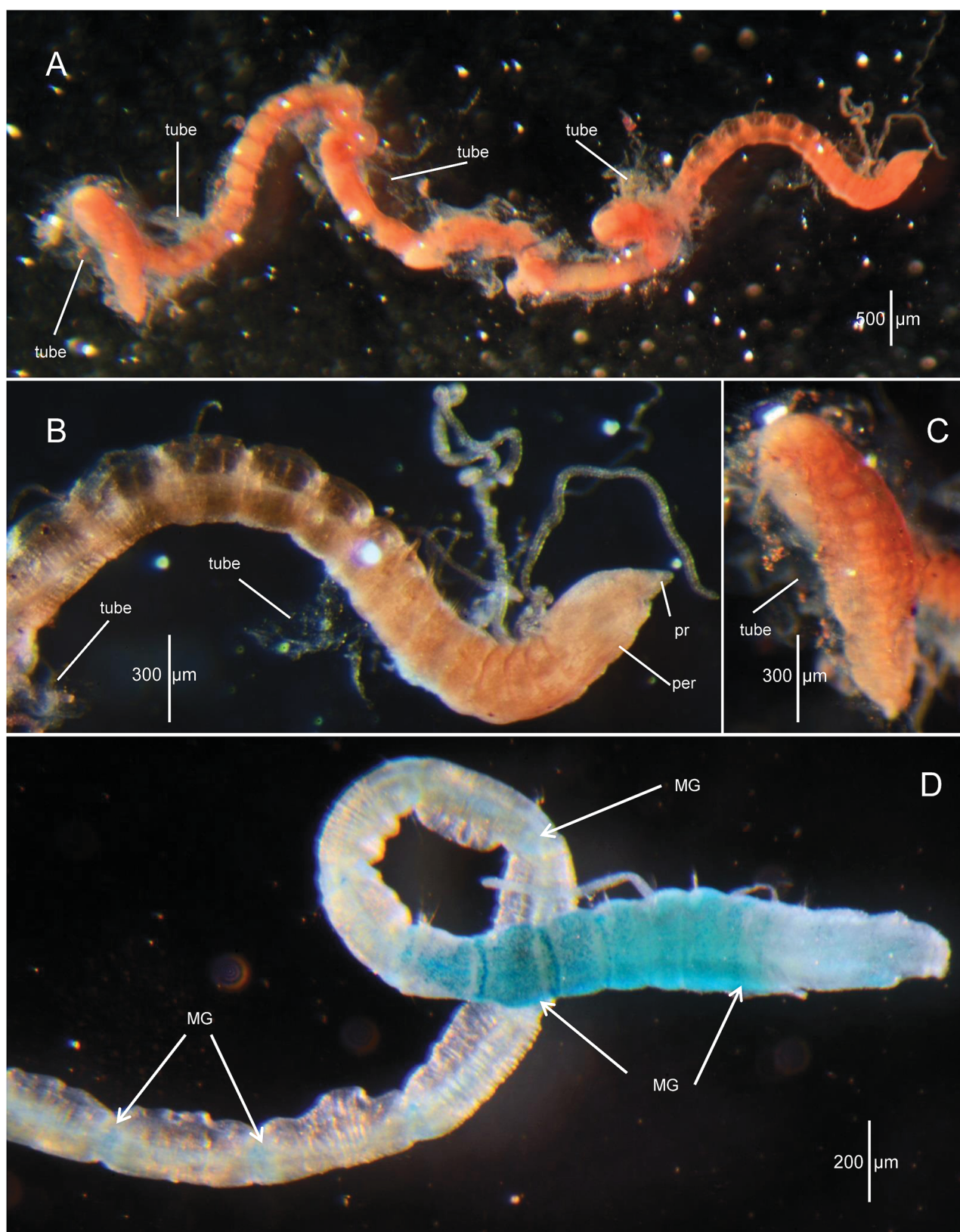


FIGURE 10. *Kirkegaardia carolina* n. sp.: A, entire animal in right lateral view, with tessellated tube; B, same, detail of anterior end; C, same, detail of posterior end with tube.—*Kirkegaardia kladara* n. sp.: D, paratype in ventral view with Methyl Green staining pattern. A–C, paratype (USNM 1407163); D, paratype (USNM 1407165). A–C stained with Shirlastain A; D, stained with Methyl Green.

Another species that is small and threadlike and that also has tessellated tubes and branchiae from setiger 1 is *K. fragilis* n. sp. from abyssal depths in the Pacific Ocean. This species however, differs from *K. carolina* n. sp. in having denticulate notosetae, a more expanded posterior end, and no annular rings on the peristomium.

Biology. *Kirkegaardia carolina* n. sp. inhabits muddy sediments in upper and middle slope depths on the continental slope off North Carolina. Data from sub-sectioned cores taken and processed individually from box cores collected in South ACSAR Cruise 1 suggest that the species occurred in the lower 2–10 cm of individual cores. Other cirratulids in the same samples were considered to be surface deposit feeders (Blake 1994).

Thin membranous tube material that is readily removed adheres to some of the paratypes (Figs. 10A–C). This is similar to the same tattered or tessellated tube material reported for *K. baptistae*, *K. tessellata*, and several other species described in this study.

Distribution. *Kirkegaardia carolina* was collected only from samples along the continental slope off Cape Lookout, North Carolina, in depths of 640–1013 m. The species did not occur on the nearby Cape Hatteras shelf or in the companion surveys off the U.S. Mid- and North Atlantic slopes.

***Kirkegaardia kladara* new species**

Figures 10D, 11

Tharyx sp. 4: Blake *et al.* 1987: C-2; Hilbig 1994: 941.

Material examined. Western North Atlantic, off Cape Lookout, North Carolina, U.S. South Atlantic ACSAR Program Cruise 1, R/V *Columbus Iselin* Sta. 1, Rep. 2, 11 November 1983, 34°16.36'N, 75°45.50'W, 640 m, coll. J.A. Blake, Chief Scientist, **holotype** (USNM 1407164); Cruise 2, R/V *Cape Hatteras*, Sta. 2, Rep. 3, 27 March 1984, 34°14.56'N, 75°43.35'W, 1000 m, coll. J.A. Blake, Chief Scientist, 1 **paratype** (USNM 1407165).

Description. An elongate, thin, fragile species; holotype complete, 24 mm long, 0.3 mm wide with about 95 setigers; paratype incomplete, 4.36 mm long, 0.23 mm wide across thorax, for 19 setigers. Body of holotype covered with closely adhering silt particles. Color in alcohol, light tan with no pigment.

Pre-setigerous region 1.8x as long as wide. Prostomium narrow, rounded on anterior margin, continuing as a narrow peristomial ridge or dorsal crest to anterior border of setiger 1 (Fig. 11A); eyes absent; nuchal organs not observed. Peristomium elongate, narrow, about 1.6x as long as wide; smooth, without obvious annulations (Fig. 11A). Dorsal tentacles arising on posterior part of peristomium with first pair of branchiae posterior to tentacles on setiger 1 at posterior margin overlying mid-dorsal groove (Fig. 11A). Subsequent branchiae in same position on following thoracic setigers. Branchiae of thoracic segments dorsal and posterior to notosetae at border with mid-dorsal channel; thereafter, parapodia shifting to lateral position in abdominal segments (Fig. 11B–C); branchiae not observed in far posterior segments.

Thoracic region with 7–9 setigerous segments, each about 3x as wide as long (Fig. 11A); abdominal segments increasing in length and decreasing in width to about 2.5x as long as wide, each more or less cylindrical with parapodia at posterior end (Fig. 11B); thoracic parapodia dorsally elevated over mid-dorsal surface forming shallow dorsal groove extending from end of peristomium posteriorly to about setiger 7 where dorsal groove ends (Fig. 11A); contained dorsal ridge extends to about setiger 5, continuing on setigers 5–7 as low elevated mid-dorsal mounds between parapodia (Fig. 11A). Body without ventral groove or ridge. Far posterior segments becoming short again, wider than long, greatly expanded posterior end terminating in pygidium with narrow pointed ventral lobe (Fig. 11C).

Parapodia reduced to low mounds from which setae project; thoracic setae consisting of long simple capillaries numbering 5–6 per notopodium and 6–8 per neuropodium; anterior abdominal noto- and neurosetae transitioning to broader capillaries with broad bases and fine denticles along margin from setigers 10–12 (Fig. 11D–E); abdominal notosetae 2–4 per notopodium; neurosetae 4–6 per neuropodium; denticles minute, pointed teeth directed lateral to main axis of shaft (Fig. 11D–E) visible at 400–1000x. Notosetae with denticles directed ventrally and denticles of neurosetae directed dorsally, *vis-à-vis*.

Methyl Green stain. Tip of prostomium lightly retaining stain; peristomium not staining. Distinctive pattern on middle and posterior thoracic segments consisting of diffuse turquoise speckles anteriorly and larger, darker turquoise speckles posteriorly (Fig. 10D); stain extends laterally up the sides of the parapodia, but does not enter

the mid-dorsal channel. Posteriorly, individual parapodia at the posterior edge of each abdominal segment stain Green (Fig. 10D); no mid-ventral stain retained.

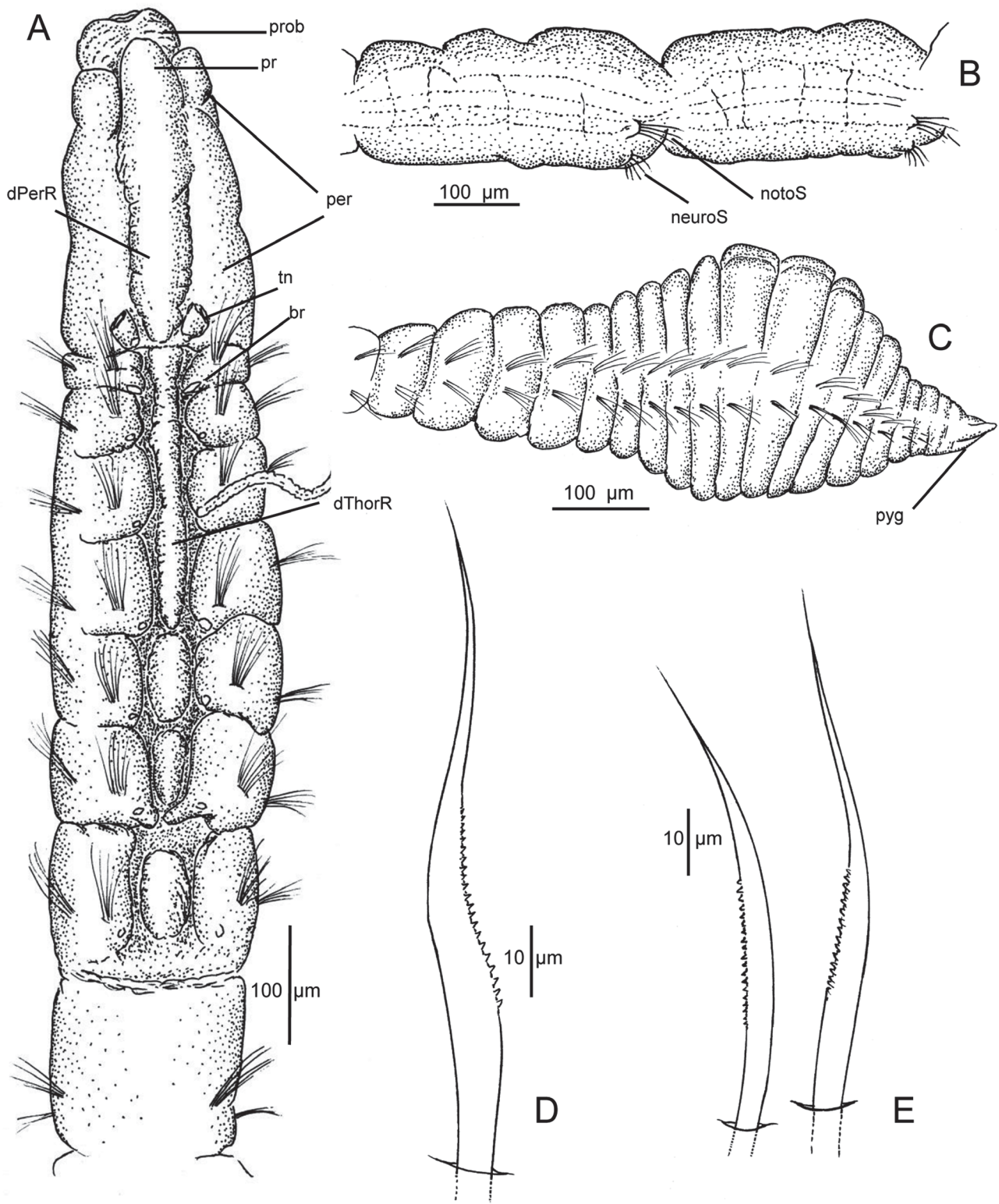


FIGURE 11. *Kirkegaardia kladara* n. sp.: A, anterior end, dorsal view; B, middle abdominal segments, left lateral view; C, posterior end, left lateral view; D, denticulated notoseta; E, denticulated neurosetae. A–B, D–E paratype (USNM 1407165); C, holotype (USNM 1407164).

Etymology. The species name *kladara* is from the Greek, *kladaros* for brittle or easily broken, referring to the thin, fragile nature of this species.

Remarks. *Kirkegaardia kladara* n. sp. has only rarely been collected most likely because of the thin, fragile nature of the body and high probability of damage during sample processing. *K. kladara* n. sp. belongs to the *K. dorsobranchialis-heterochaeta* group of 12 species in having the thoracic parapodia elevated and producing a mid-dorsal channel between them. Of these, *K. kladara* n. sp. is one of four species having a peristomium with a dorsal ridge extending along its entire length. *K. kladara* n. sp. differs from *K. annulosa* and the others in this group of four by having the first pair of branchiae arising from setiger 1 instead of lateral to the dorsal tentacles on the peristomium. Furthermore, the short, rounded prostomium that is continuous with the mid-dorsal peristomial ridge differs from these species and other species of the genus *Kirkegaardia*. Other details are presented in the Remarks for *K. annulosa* (see above).

Distribution. *Kirkegaardia kladara* was collected only from samples taken in muddy sediments along the continental slope off Cape Lookout, North Carolina, in depths of about 640–1000 m. The species was not identified on the nearby Cape Hatteras shelf or in the companion surveys off the U.S. Mid- and North Atlantic slopes.

***Kirkegaardia hampsoni* new species**

Figures 12–13

Tharyx dorsobranchialis: Maciolek-Blake *et al.* 1985: 75, 142, Appendix B-3, Appendix D-8. Not Kirkegaard 1959.

Monticellina dorsobranchialis: Blake, 1991 (In part); Hilbig & Blake 2000: 162.

Type Material examined. **Western North Atlantic, Offshore New England, Georges Bank**, BIMP, Cruise M-8, R/V *Gyre*, Sta. 13, 21 May 1983, coll. G. Hampson, WHOI, Chief Scientist, 40°29.5'N, 70°12.6'W, 70 m, **holotype** and 34 **paratypes** (USNM 1407138–9); Cruise M-1, R/V *Eastward*, Sta. 13, 9 July 1981, coll. M. Rawson, Lamont-Doherty Geological Observatory, Chief Scientist, 40°29.5'N, 70°12.6'W, 70 m, 34 **paratypes** (USNM 1407140); Cruise M-2, R/V *Oceanus*, Sta. 13, 09 Nov 1981, coll. M. Rawson, Lamont-Doherty Geological Observatory, Chief Scientist, 40°29.5'N, 70°12.6'W, ~70 m, 52 **paratypes** (USNM 1407141); Cruise M-3, R/V *Endeavor*, Sta. 13, 11 Feb 1982, coll. G. Hampson, WHOI, Chief Scientist, Sta. 40°29.5'N, 70°29.2'W, 69 m, 65 **paratypes** (USNM 1407142); Cruise M-4, R/V *Cape Henlopen*, Sta. 13, coll. G. Hampson, WHOI, Chief Scientist, 18 May 1982, 40°29.3'N, 70°12.5'W, 70 m, 29 **paratypes** (USNM 1407143); Cruise M-5, R/V *Oceanus*, Sta. 13, 28 Jul 1982, coll. G. Hampson, WHOI, Chief Scientist, 40°29.3'N, 70°12.6'W, 62 m, 4 **paratypes** (USNM 1407144); Cruise M-6, R/V *Oceanus*, Sta. 13, 27 Nov 1982, coll. G. Hampson, WHOI, Chief Scientist, 40°29.3'N, 70°12.4'W, 67 m, 35 **paratypes** (USNM 1407145); Cruise M-7, R/V *Endeavor* Sta. 13, 11 Feb 1983, coll. G. Hampson, WHOI, Chief Scientist, 40°29.3'W, 70°12.5'W, 66 m, 66 **paratypes** (USNM 1407146).

Other material examined. **Offshore New England, Georges Bank**, BIMP, Cruise M-6, R/V *Oceanus*, Sta. 9, 26 Nov 1982, coll. G. Hampson, WHOI, Chief Scientist, 40°26.7'N, 68°09.8'W, 141 m, 10 specimens (USNM 1407148); Sta. 12, 26 Nov 1982, coll. G. Hampson, WHOI, Chief Scientist, 40°22.2'N, 68°29.8'W, 103 m, 28 specimens (USNM 1407147); Sta. 13A, 27 Nov 1982, coll. G. Hampson, WHOI, Chief Scientist, 40°30.0'N, 71°00'W, 78 m, 64 specimens (USNM 1407149).—Cruise M-8, R/V *Gyre*, Sta. 12, 20 May 1983, coll. G. Hampson, WHOI, Chief Scientist, 40°22.2'N, 68°29.7'W, 105 m, 21 specimens (USNM 1407150); Sta. 13A, 21 May 1983, coll. G. Hampson, WHOI, Chief Scientist, 40°30.0'N, 71°00.6'W, 80 m, 61 specimens (USNM 1407151).—**Massachusetts Bay**, MWRA long-term monitoring program, R/V *Aquamonitor*, Sta. NF-14, Rep. 1, 31 Jul 2007, coll. P. Neubert, 42.387°N, 70.823°W, 34.2 m, 42 specimens (MCZ 135290); Sta. FF-01A, Rep. 2, 30 Jul 2007, coll. P. Neubert, 42.564°N, 70.676°W, 35.8 m, 8 specimens (MCZ 135291).—**Long Island Sound**, New London, historical dredged material disposal site, Sta. AC3, 17 February, 2000, 41°16.471'N, 72°04.459'W, 33 specimens (JAB).

Description. An elongate, often thread-like species with length and number of setigerous segments variable and age dependent. Holotype complete, 10.7 mm long, 0.23 mm wide across thorax and 0.20 mm wide across abdominal segments, with 110 setigers; a mostly complete, slender paratype 14 mm long, 0.2 mm wide across thorax with about 60 setigers compared to more robust paratype 15 mm long, 0.3 mm wide across thorax with 106 setigers. Complete specimens, including holotype, with bodies coiled precluding exact measurements.

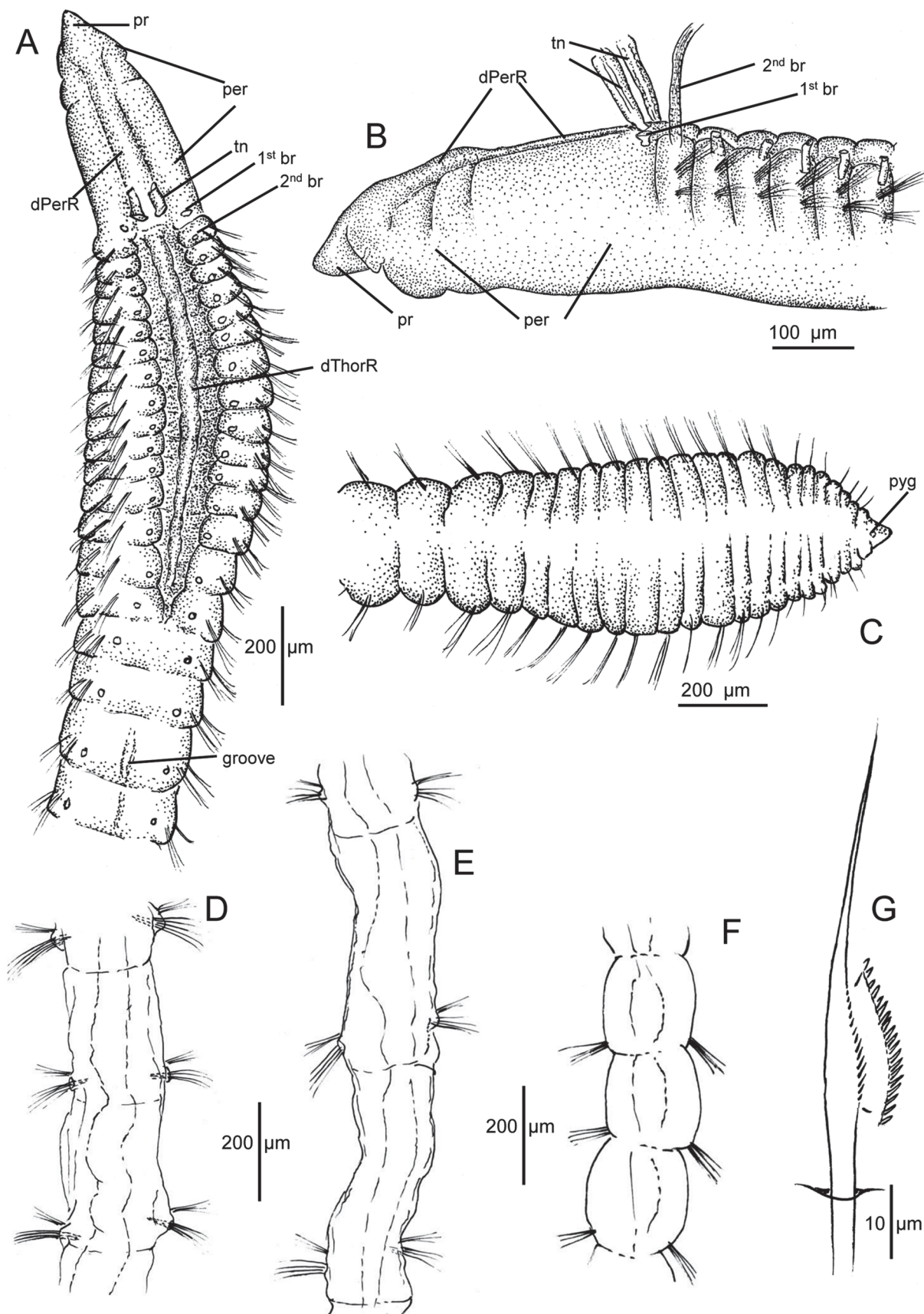


FIGURE 12. *Kirkegaardia hampsoni* n. sp.: A, anterior end, dorsal view; B, anterior end, left lateral view; C, posterior end, dorsal view; D, setigers 19–21; E, setigers 26–28; F, setigers 57–59; G, posterior neuroseta. A–F, paratypes from Cruise M8 Sta. 13 from off Georges Bank (USNM 1407139); G, same sample, holotype (USNM 1407136).

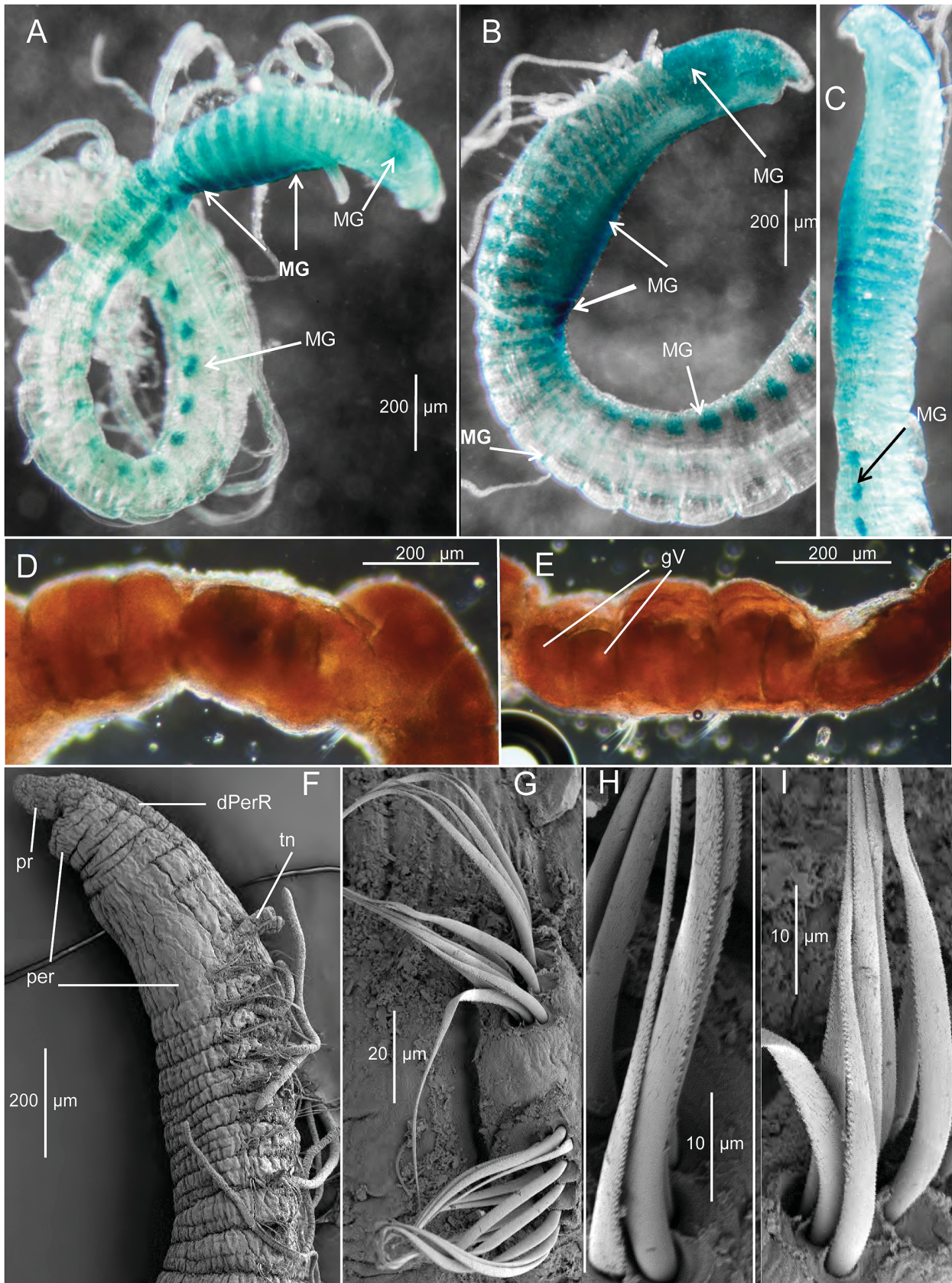


FIGURE 13. *Kirkegaardia hamptoni* n. sp.: A–C, three paratypes from Georges Bank Cruise M8 Sta. 13 (USNM 1407139) showing Methyl Green staining patterns; D–E, specimen from Cruise M-4, Sta. 13 (USNM 1407143) from off Georges Bank showing ovigerous segments with large eggs; F–I, SEMs from Massachusetts Bay specimen: F, anterior end, left lateral view; G, middle abdominal parapodium showing noto- and neurosetae; H, notoetae; I, neurosetae.

Pre-setigerous region about 2.5x as long as wide in smaller, more slender specimens; 2.0–2.3x as long as wide in larger more robust specimens (Figs. 12A, 13F). Prostomium triangular, tapering to narrow rounded apex (Figs. 12A–B, 13F); eyes absent; slit-like nuchal organs present on posterior lateral margins. Peristomium elongate, smooth without obvious annulations in smaller specimens, but with 1–2 lateral grooves in larger specimens immediately posterior to prostomium, main part of peristomium remaining smooth (Fig. 12A–B). Peristomial mid-dorsal ridge present, extending from prostomium to border of setigerous region (Figs. 12A–B, 13F). Dorsal tentacles on posterior part of peristomium, first pair of branchiae also on peristomium, posterolateral to tentacles, in line with second pair of branchiae on setiger 1 (Figs. 12A–B, 13F). Branchiae of thoracic segments dorsal to notosetae at border with mid-dorsal channel; thereafter, parapodia shifting to lateral position in abdominal segments; branchiae not observed in far posterior segments.

Parapodia of thoracic region elevated above dorsal midline producing shallow mid-dorsal channel or groove between parapodia (Fig. 12A), continuing to start of abdominal segments; dorsal thoracic channel with elevated narrow ridge along most of length (Fig. 12A); thoracic region with 10–15 setigerous segments depending on age of specimens; slender, less mature specimens with fewer, larger more robust specimens with maximal numbers of thoracic setigers. Abdominal region with narrow mid-dorsal furrow or groove over a variable number of segments (Fig. 12A); far posterior segments becoming shorter and wider, forming weakly expanded posterior section terminating in pygidium with dorsal anus overlying conical lobe (Fig. 12C).

More slender specimens with most abdominal segments 2–3x as long as wide (Fig. 12D–E) with posterior segments becoming shorter, almost moniliform (Fig. 12F); more robust specimens with most abdominal segments as long as wide with elongate segments limited to far posterior, demonstrating a pattern of growth and maturation of body segments. Larger specimens typically with mature gametes, absent in more slender immature specimens.

Parapodia reduced to low mounds from which setae project; thoracic setae consisting of long simple capillaries numbering 7–12 per notopodium and 6–10 per neuropodium; anterior and middle abdominal segments with about 8–12 setae per noto- and neuropodia (Fig. 13G); far posterior abdominal segments with 5–8 setae per notopodium and 5–6 per neuropodium; neurosetae becoming shorter, wider basally in middle abdominal segments with minute denticles along one edge (~setiger 50 in largest specimens), visible from 400–1000x (Figs. 12G, 13I); notosetae also becoming broad and denticulated in middle abdominal segments, denticles best seen at 1000x (Fig. 13H). Notosetae with denticles directed ventrally and denticles of neurosetae directed dorsally, *vis-à-vis*.

Methyl Green stain. Prostomium generally not staining; some specimens, however, with prominent dorsal patch and lateral lines of light green on the peristomium (Fig. 13B), others with patch lighter, fading rapidly (Fig. 13A); thoracic region with 8–10 segments with distinct ventral bands of dark blue extending dorsally to near mid-dorsal channel, 4–6 of these bands remaining prominent, being the last stain to fade away (Fig. 13A–C); prominent mid-ventral longitudinal line present on most anterior abdominal segments (Fig. 13A–C), broken between segments; lateral intersegmental spots absent but thin lines on dorsal side of abdominal segments represents stain in intersegmental grooves (Fig. 13B).

Etymology. This species is named for the late Mr. George Hampson, scientist at the Woods Hole Oceanographic Institution. Mr. Hampson was Chief Scientist on the Georges Bank monitoring surveys and the North Atlantic ACSAR surveys in the 1980s. He was also a key field leader on several of our deep-water surveys off northern California in the 1980s and 1990s. He was a mentor to many young marine scientists and provided training on how to collect samples offshore and correctly process them.

Remarks. *Kirkegaardia hampsoni* n. sp. is most similar to the deeper water U.S. Atlantic species *K. annulosa* and the shallow-water Mediterranean species *K. heterochaeta* in general body form and MG staining patterns. Although both *K. annulosa* and *K. heterochaeta* have the entire surface of the mid-dorsal channel raised into a ridge, the configuration of this differs from that of *K. hampsoni* n. sp. because the latter has a separate ridge located on the floor of the channel. As part of the larger review of species in this study, *K. hampsoni* n. sp. belongs to a group of four species, including *K. annulosa*, *K. kladara* n. sp., and *K. cristata* n. sp. that have a mid-dorsal ridge along the entire length of the peristomium. *K. kladara* n. sp. differs significantly from each of these species in having the first pair of branchiae on setiger 1 instead of on the peristomium lateral to the dorsal tentacles. *K. cristata* n. sp. from the northeastern Pacific has a different MG staining pattern and up to four peristomial annular rings instead of up to three annuli in *K. hampsoni* n. sp.

Biology. *Kirkegaardia hampsoni* was a dominant species at Station 13, the so-called “mud patch” adjacent to

Georges Bank (Maciolek-Blake *et al.* 1985). The species is generally found in finer-grained sediments than its congener *K. baptistae* which, on Georges Bank, prefers sediments having coarser grains.

A few specimens from the February and May 1982 collections at Georges Bank Sta. 13 were females with eggs observed in posterior abdominal segments. At least two specimens were males with numerous sperm packets loose in the coelomic fluid; these sperm had a minute rounded nucleus. The eggs from the February specimens measured 106–122 μm in one specimen and ca. 150–152 μm in another; there were about 4–6 eggs per segment. In contrast, eggs from the May collection were considerably larger, measuring 160–183 μm in diameter (average = 177.1 μm ; 1 SD = 10.6 μm), with four eggs per segment (Fig. 13D–E). In some segments the largest eggs were compressed anterior to posterior with individual segments being elevated and dorsally rounded due to the contained eggs. There were no apparent females in either the July or November samples. Although scanty, these results suggest that in this area gametes of *K. hampsoni* develop and mature in January–February and the worms likely spawn in April–May.

Distribution. *Kirkegaardia hampsoni* n. sp. has been recorded locally as *Tharyx* and/or *Monticellina dorsobranchialis* from numerous locations on the U.S. Atlantic continental shelf from the Gulf of Maine to the mid-Atlantic, 30–150 m. Records from further south and the Gulf of Mexico should be examined as they could possibly belong to different species.

***Kirkegaardia neotesselata* new species**

Figures 14, 15A–C

Tharyx annulosus: Maciolek *et al.* 1987: Appendix D-2 (In part, Sta. 11). Not Hartman (1965).

Material examined. Western North Atlantic, Offshore New England, Georges Bank, continental slope south Cape Cod, US North Atlantic ACSAR Program, Cruise 2, R/V *Oceanus*, Sta. 11, Rep. 2, 04 May 1985, coll. G. Hampson, WHOI, Chief Scientist, 40°01.28'N, 70°55.09'W, 250 m, **holotype** and 7 **paratypes** (USNM 1407135–6).

Description. Holotype, complete, 10 mm long, 0.26 mm wide across thoracic segments for about 75 setigers; however an exact segment count not possible due to worms being enclosed in tube materials (Fig. 15A–C). Body elongate, cylindrical throughout, with body segments wider than long in thoracic and anterior abdominal segments, becoming longer posteriorly, with some appearing oval or moniliform in shape; segments becoming narrow and crowded in far posterior segments forming an expanded posterior end terminating in a simple pygidium with terminal anus and single ventral lobe (Fig. 14B).

Pre-setigerous area somewhat bullet-shaped, 1.5x as long as wide; prostomium short, triangular, and narrowing to a pointed tip (Fig. 14A); nuchal organs at posterior-lateral margin; eyes absent. Peristomium with three lateral grooves producing up to four annular rings only apparent laterally (Fig. 14A); dorsum elevated, with mid-dorsal ridge along most of peristomium, continuing along mid-dorsal thoracic groove (Fig. 14A). Peristomium ending at anterior border of setiger 1, with demarcation clearly evident; dorsal tentacles arising from posterior margin (Fig. 14A). First pair of branchiae on setiger 1, dorsal to notosetae (Fig. 14A).

Thoracic region with about 10 setigers, but overall nature of anterior end obscured on several specimens due to tightly adhering tube material; channel between parapodia with a narrow mid-dorsal ridge present, continuing from peristomium and extending for 6–7 setigers, then merging with mid-dorsum and disappearing (Fig. 14A).

Parapodia weakly defined with only low tori from which setae arise. Notosetae long, slender, simple capillaries in anterior setigers, numbering about 6–8 per fascicle, some becoming thicker in mid-body segments, none with serrations or denticles; thoracic neurosetae short simple capillaries numbering 5–8 per fascicle in thoracic segments, becoming wider basally, with serrated edges present on setae of anterior abdominal segments (setigers 11–12) continuing to near posterior end (Fig. 14C); noto- and neurosetae of posterior setigers reduced to 2–4 per fascicle.

Methyl Green stain. Stain is retained on the prostomium and as stripes on the venter of posterior thoracic and anterior abdominal segments on the anterior border of each segment; these stripes generally encircle each segment up the lateral and dorsal most sides of each parapodium involved. No stain is retained on the peristomium, anterior thoracic segments, or the expanded posterior section.

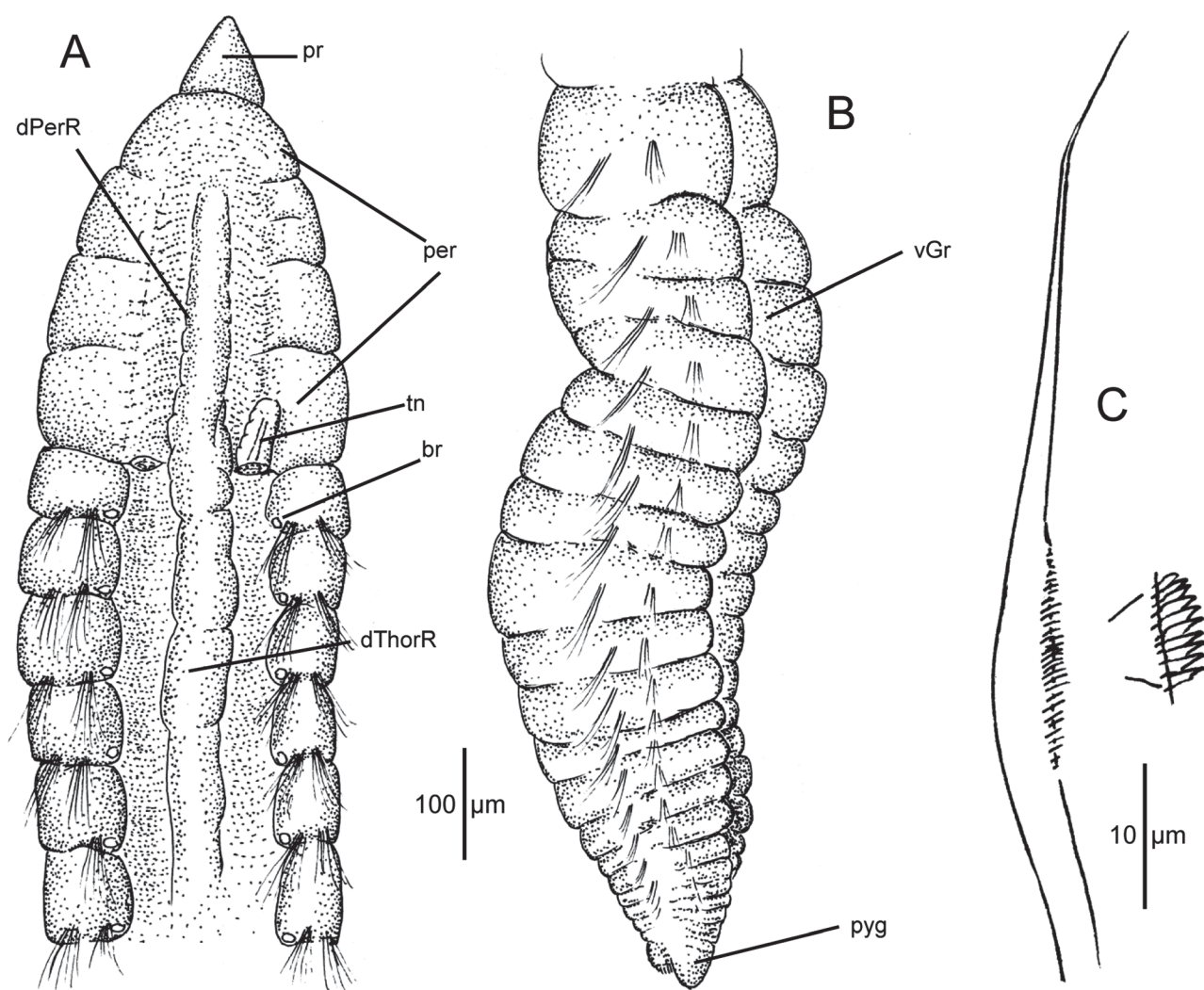


FIGURE 14. *Kirkegaardia neotesselata* n. sp.: A, anterior end, dorsal view; B, posterior end, left ventrolateral view; C, denticulated neuroseta. (paratypes, USNM 1407136).

Etymology. The epithet *neotesselata* is derived the Latin, *neo* for new and *tesselatus* for a mosaic and is derived from the name of its Pacific congener, *K. tessellata*, due to its having a similar tessellated tube structure.

Remarks. Eight specimens similar to *K. tessellata* from California were found in a sample from off New England in upper continental slope depths. The specimens were all enclosed by filamentous tube materials through which branchiae projected in groups at intervals along the body (Fig. 15A–C). This tube structure is similar in appearance to the tessellated or tattered tubes reported by Hartman (1960) and Blake (1996) for *K. tessellata* from offshore California. However, the tube material of the New England specimens is a hardened substance within which the worms are compressed and twisted upon preservation and from which they are difficult to extract; whereas, the tube material of *K. tessellata* is soft and pliable such that worms are easily removed intact. Further, careful inspection of these New England specimens revealed a species having a different morphology despite the similar appearing tube.

The most obvious morphological difference is that the parapodia of thoracic segments are elevated sufficiently high to produce a low mid-dorsal channel that is not evident in *K. tessellata*. The peristomium of *K. neotesselata* n. sp. is incised with three lateral grooves producing up to four annulated rings; in contrast, *K. tessellata* has a smooth peristomium with no evidence of annular rings. In addition, the peristomium has a mid-dorsal ridge that continues posteriorly as a mid-dorsal thoracic ridge within the dorsal channel. A mid-thoracic ridge is also present in *K. tessellata*, but it is not within a mid-dorsal thoracic channel. Finally, a MG staining pattern has not been observed for *K. tessellata*; in *K. neotesselata* n. sp., however, the prostomium stains and stripes are present on the venter of posterior thoracic and anterior abdominal segments.

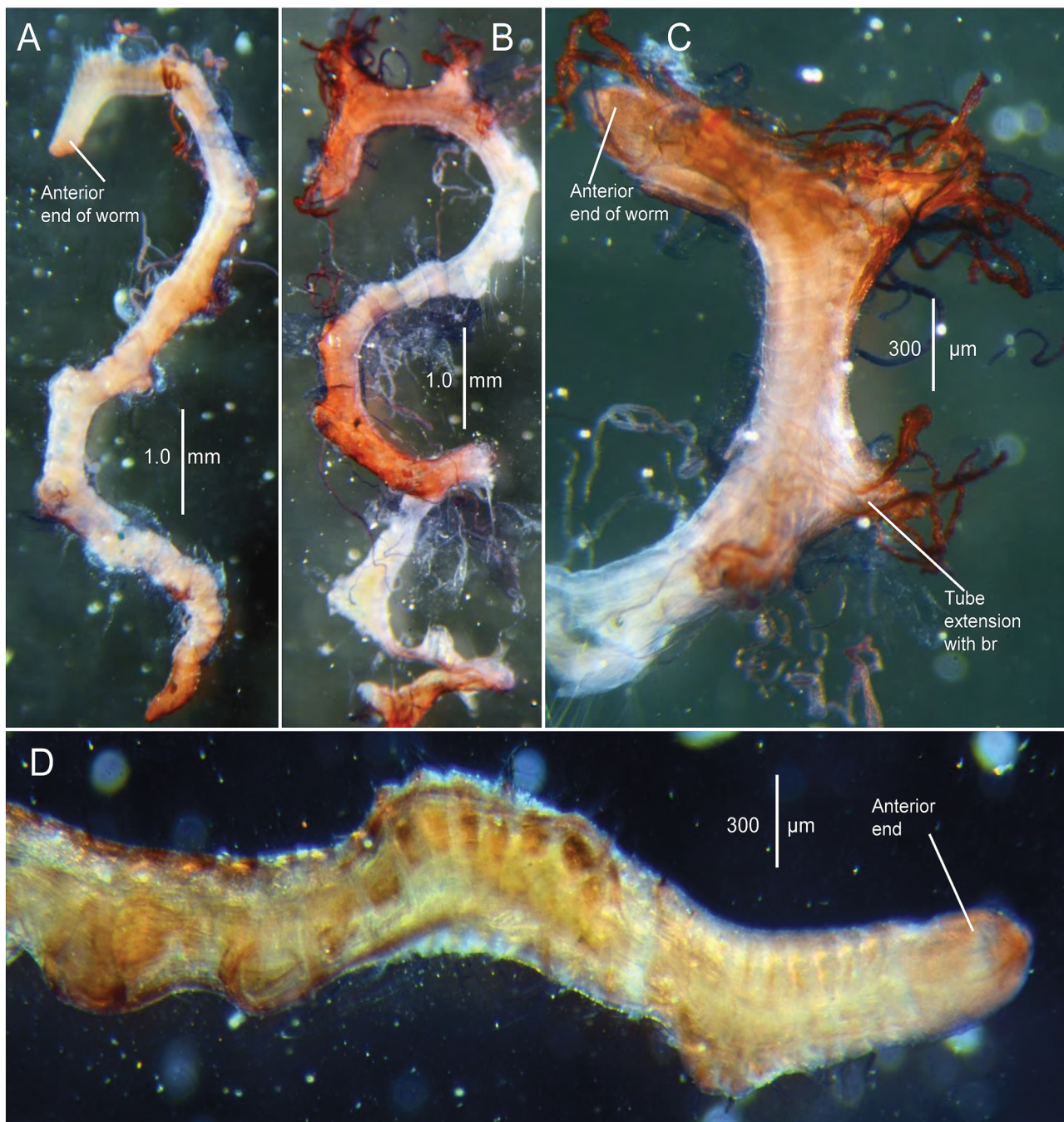


FIGURE 15. *Kirkegaardia neotesselata* n. sp.: A–C, photomicrographs of paratypes (USNM 14307136) within tessellated tubes; head of animal at the top.—*Kirkegaardia* sp. A, D, photomicrograph of specimen within tessellated tube, anterior end to the right (MCZ 35293).

Locally off New England, *K. neotesselata* n. sp. is most closely related to *K. baptistae*, which has also been found to have tessellated tubes. However, the tubes of *K. baptistae* are soft and pliable as in *K. tessellata* and not the tougher tube material of *K. neotesselata* n. sp. Additionally, *K. baptistae* has denticulated notosetae instead of lacking them, has no dorsal peristomial or thoracic ridge and while the parapodia are enlarged into prominent shoulders, the mid-dorsum is actually domed or elevated rather than weakly depressed.

Biology. These specimens were removed from a sample containing *K. annulosa* and specimens of *Aphelochaeta* spp. It is likely that additional records of *K. neotesselata* will be found in similar samples. The tough, closely adhering tubes readily separate this species from other cirratulids in the same samples.

Distribution. New England upper continental slope, 250 m.

***Kirkegaardia* sp. A**

Figure 15D

Monticellina cf. *tesselata*: Çinar 2005: 150. Not Hartman 1960.

Monticellina tessellata: Çinar *et al.* 2014:748. Not Hartman 1960.

Material examined. **Mediterranean Sea**, France, Golfe de Fos, west of Marseille, 42 m, coll. 1979, C. Salen-Picard, donated by L. Laubier, 1 specimen (MCZ 135293).

Description. An incomplete specimen from the French Mediterranean coast measures 8 mm long, 0.4 mm wide for about 55 setigers; many segments twisted due to shape imposed by tube adhering after preservation (Fig. 15D). Color in alcohol: tan, lacking distinct body pigment.

Prostomium conical, short, bluntly rounded on anterior margin. Pre-setigerous area somewhat bullet-shaped with at least two visible lateral grooves and a distinct mid-dorsal ridge extending from posterior margin of prostomium to end of the peristomium. Peristomium about 2–3x as long as wide, eyes and nuchal organs not discernible. Parapodia dorsally elevated producing a mid-dorsal channel with a contained ridge more or less continuous with the mid-peristomial ridge, but appears separated by a gap between end of peristomium and anterior margin of mid-dorsal channel. Dorsal tentacles arise at end of the peristomium; first branchiae on setiger 1.

Thoracic region with 12–14 setigers, but overall nature of body regions obscured by twisted segments due to preservation within tube. Thoracic segments crowded, narrow; these becoming longer, about as wide as long in middle body. Anterior noto- and neurosetae long and slender; elevated parapodia with no distinct tori, setae appearing to arise directly from body wall. Setae of middle body segments arising more laterally. Notoetae all simple capillaries. Neurosetae of middle and posterior body segments shorter than notoetae and with a row of fine denticles along margin. Nature of pygidium unknown.

Methyl Green stain. No MG staining reaction was seen on the single specimen available.

Remarks. This is a small, probably undescribed species of *Kirkegaardia* with a tightly adhering tube that was extremely difficult to remove without damaging the specimen (Fig. 15D). The species has been referred to as *Monticellina* cf. *tesselata* by Mediterranean workers because of the similarity of the tightly adhering tessellated tubes to those figured for Hartman's species. However, a comparison of this single specimen with both *Kirkegaardia tessellata* and the new North American Atlantic species, *K. neotesselata* n. sp., suggests a closer relationship to the latter than to the former because the tube materials are of a hardened and tough texture instead of soft and pliable as in *K. tessellata*. Further, there is a mid-dorsal ridge on the peristomium and elevated thoracic parapodia with a mid-dorsal channel containing a ridge. *K. tessellata* on the other hand, has no mid-dorsal peristomial ridge and the parapodia are not as elevated dorsally; however, it does have a mid-dorsal thoracic ridge. Further, the peristomium of the Mediterranean specimen has lateral grooves similar to those for *K. neotesselata* n. sp.; these are lacking in *K. tessellata*. Additional specimens are required before this species can be better compared with its congeners.

Distribution. The species has been recorded from the Mediterranean coast of France and the eastern Mediterranean Sea in shallow subtidal sediments.

Species of *Kirkegaardia* from the Northeastern Pacific and Central Pacific Abyssal Plain

***Kirkegaardia serratiseta* (Banse & Hobson, 1968) new combination**

Figure 16

Tharyx serratisetis Banse & Hobson, 1968: 39–40, Fig. 7k–l; Hobson & Banse 1981: 553, Fig. 9m.

Aphelochaeta serratiseta: Blake 1991: 28.

Monticellina serratiseta: Blake 1996: 325–324, Fig. 8.25; Welch & Dutch 2014: 5–7, 8 figs.

Not *Monticellina* cf. *serratiseta*: Diaz-Diaz *et al.* 2014: 357–358, Fig. 2 f–i.

Material Examined. **Northeastern Pacific, Puget Sound**, East Anderson Island, Sta. 44, Rep. 1, 07 April 1992, 47.16133°N, 122.67358°W, 20 m, 3 specimens (MSMP AN295); Shoreline Elliott Bay, Sta. 181, Rep. 1, 18 June 1998, 47.61504°N, 122.36230°W, 36.7 m, 2 specimens (MSMP AN1084); Magnolia Bluff, Sta. 32, Rep. 5, 25 March 1990, 47.63192°N, 122.40850°W, 21 m, 1 specimen (MSMP AN2345).

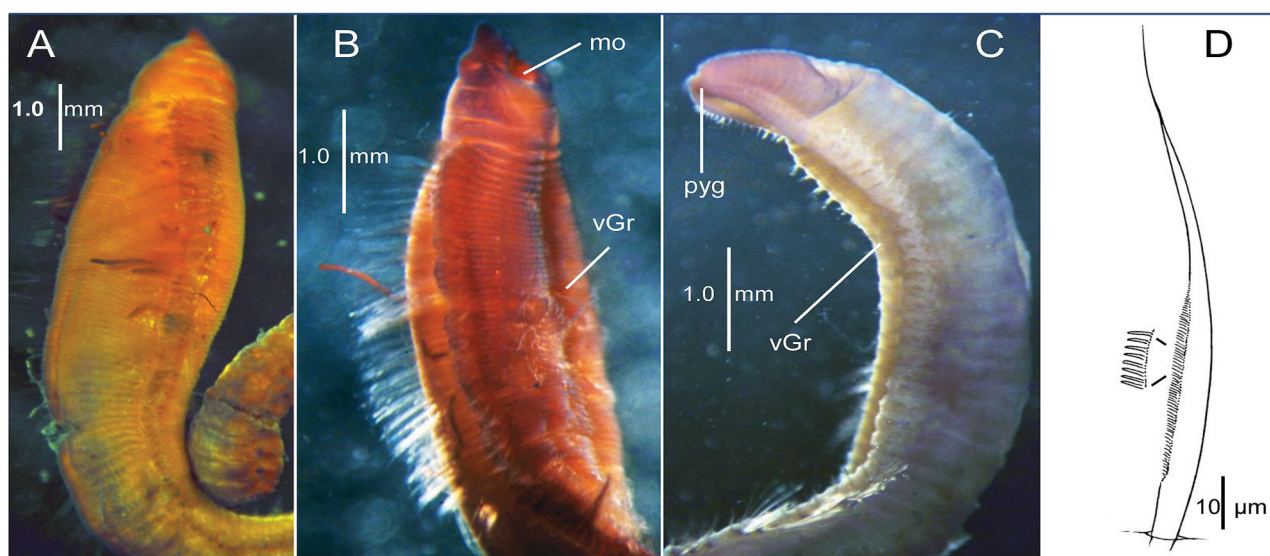


FIGURE 16. *Kirkegaardia serratiseta* (Banse & Hobson, 1968), specimens from Puget Sound: A, anterior end, right lateral view; B, anterior end, right ventrolateral view; C, posterior end, ventrolateral view; D, denticulated neuroseta. A–B, stained with Shirlastain A. A–B (MSMP AN295); C–D (MSMP AN1084).

Description. A large species, complete specimen from Sta. 181, 40 mm long, 1.8 mm wide across thorax with about 300 setigerous segments; all segments narrow, crowded. Thoracic region with about 50 setigers, gradually transitioning into abdominal segments; these also narrow and crowded (Fig. 16A–B). Noto- and neuropodia closely spaced, located in raised mounds extending as shoulders along body (Fig. 16A); in cross section, thoracic region high, rounded dorsally well above parapodia, flattened, slightly concave ventrally with distinct ventral groove; middle and posterior segments with deep ventral groove with parapodial shoulders shifting ventrally, forming sides of groove (Fig. 16C). Far posterior end gradually narrowing with pygidium consisting of a simple ventral lobe below anal opening (Fig. 16C). Color in alcohol light tan to brown; posterior thoracic segments sometimes appearing creamy in color but not glandular as with some species of *Aphelochaeta*.

Prostomium triangular to conical, pointed on anterior margin (Fig. 16A–B); eyes lacking; nuchal organs curved grooves on posterior border; prostomium and peristomium together slightly longer than wide (Fig. 16A–B); peristomium typically with three annular rings (Fig. 16A–B); dorsal tentacles medial, arising at level of setiger 1 on posterior medial extension of peristomium. First pair of branchiae arising lateral to dorsal tentacles on anterior margin of setiger 1; second branchiae on posterior margin of setiger 1 dorsal to notosetae; subsequent branchiae in same position on setiger 2 and following setigers.

Parapodia well developed anteriorly, produced into expanded tori bearing dense fascicles of 25 or more long, smooth, silky capillary setae (Fig. 16B); middle segments similar, with long, smooth notosetae and shorter, broad, distinctly serrated or denticulated neurosetae (Fig. 16D); posterior setae short, reduced to 5–8 per fascicle; denticulated notosetae absent; serrated neurosetae not apparent on last few setigers; denticulated neurosetae with numerous tightly spaced denticles along one edge; denticles apparent only at 1000x (Fig. 16D).

Methyl Green stain. Stain not retained anywhere on the body after differentiation.

Remarks. *Kirkegaardia serratiseta* is an unusual species; with its large robust size, morphology of the pre-setigerous region, and numerous crowded segments with dense fascicles of long, silky capillaries, it superficially resembles species of *Aphelochaeta* rather than *Kirkegaardia*. Indeed, the only character allying the species to *Kirkegaardia* is the denticulated or serrated neurosetae.

The record of *M. cf. serratiseta* by Diaz-Diaz *et al.* (2014) from Venezuela is of a different species because the prostomium is longer than wide and lacks any annulations (Diaz-Diaz *et al.* 2014: Fig. 2f) despite the text stating there are three; in addition, the pygidium is of a different morphology.

Biology. *Kirkegaardia serratiseta* occurs in sediments consisting mostly of sand and lesser amounts of silt and clay (Banse & Hobson 1968). Blake (1996) reported one specimen with eggs measuring 110 x 150 µm.

Distribution. Known only from the Puget Sound in sandy sediments, 9–84 m.

***Kirkegaardia luticastella* (Jumars, 1975) new combination**

Figure 17

Tharyx luticastellus Jumars, 1975: 341–348, figs. 1–2.

Monticellina luticastella: Blake 1996: 322–323, fig. 8.23.

Material examined. California continental slope, west of Farallon Islands, San Francisco Deep Ocean Disposal Site (SF-DODS) September 2006 monitoring survey, R/V *Point Sur*, Sta.57, 37°42.946'N, 123°32.947'W, 2637 m, 24 Sep 2006, coll. J.A. Blake, 1 specimen (LACM-AHF Poly 8929).

Description. Farallons specimen complete, in two parts, 6 mm long, 0.7 mm wide across the thorax for about 30 segments. Thoracic region expanded, with seven setigerous segments followed by moniliform abdominal segments (Fig. 17A). Thoracic setigers all similar, short, dorsally elevated over midline forming shallow groove (Fig. 17A); these abruptly transitioning to anterior abdominal segments each about as long as wide, distinctly moniliform (Fig. 17A–B). Posteriormost segments becoming narrow, more crowded, terminating in simple pygidium with ventral lobe (Fig. 17B).

Pre-setigerous region enlarged, bulbous, as wide as long, together with thick thoracic region forming enlarged, thickened anterior end (Fig. 17A). Prostomium broadly triangular, narrowing to rounded anterior margin (Fig. 17A); posterior dorsal margin merging indistinctly with peristomium; nuchal organs not observed; eyes absent. Mouth large, with emerging bulbous proboscis (Fig. 17A), surrounded by thick lateral peristomial lips. Peristomium smooth dorsally, weak lateral groove dividing peristomium into two annular rings, apparent only laterally and not prominent (Fig. 17A). Dorsal tentacles arising from between posterior margin of peristomium and anterior border of setiger 1 (Fig. 17A); first pair of branchiae arising lateral to dorsal tentacles on posterior margin of peristomium; second pair of branchiae arising from posterior margin of setiger 1, with subsequent thoracic branchiae in similar position (Fig. 17A). Branchiae of abdominal segments evident on a few moniliform segments, arising laterally, dorsal to notosetae; all branchiae thin, relatively short, most missing.

Parapodia of thoracic region small mounds from which setae arise. Notoetae elongate, smooth capillaries throughout, numbering 12–15 per notopodium in thoracic region, same in abdominal segments, reduced to 8–10 in posterior segments. Neurosetae similar in number and appearance in thoracic segments; transitioning to short, denticulated capillaries on setigers 9–10 (Fig. 17A). Denticles of neurosetae very fine, visible at 400x, but with details apparent only at 1000x, each seta observed to have numerous curved and pointed denticles along one narrow margin (Fig. 17C–D).

Methyl Green stain. Some stain retained on anterior margin of prostomium and on the posterior borders of the first and second peristomial rings; retention is weak.

Remarks. A single complete specimen of *Kirkegaardia luticastella* was collected on the continental slope west of San Francisco, California as part of a long-term monitoring effort at SF-DODS. *K. luticastella* was the first mud ball worm to be described and this represents the first record of the species since the original collection from the San Diego Trough (Jumars 1975). The specimen is smaller than reported for the types by Jumars (1975) and Blake (1996), being only 6 mm long and 0.7 mm wide instead of 15–30 mm long and 2 mm wide and with only 30 setigerous segments instead of 48–69. In addition, the Farallons specimen has only seven thoracic segments instead of 10–11 as in the type specimens. The position of the first pair of branchiae on the peristomium, recorded here for the northern California specimen, differs from the descriptions by Jumars (1975) and Blake (1996), which were based on the type collection from southern California. The branchiae were described as first occurring on setiger 1; however, Shirlastain A was used with the new material but not on the type specimens. It is likely that the same pre-setiger branchiae will be found on the type specimens when they are rechecked using the stain as they are present in both *K. jumarsi* n. sp. and *K. olgahartmanae* n. sp., two new mud ball worms reported in this study.

Despite these differences in size, numbers of segments, and location of the first pair of branchiae, the main features described for the species by Jumars (1975) and Blake (1996) are consistent. The prostomium is bluntly rounded on the anterior margin and the peristomium is relatively short, being generally wider than long, for a species of *Kirkegaardia*. Jumars (1975) illustrated a distinct groove in the peristomium producing two annular rings; Blake (1996) illustrated only a weak lateral groove on the holotype; a more prominent lateral groove on the Farallons specimen produces a lateral separation of the peristomium into two more-or-less equal annular rings. However, peristomial rings are often more or less prominent depending on contraction during preservation; often the grooves that define annular rings can be observed only with stains such as Shirlastain A or with SEM.

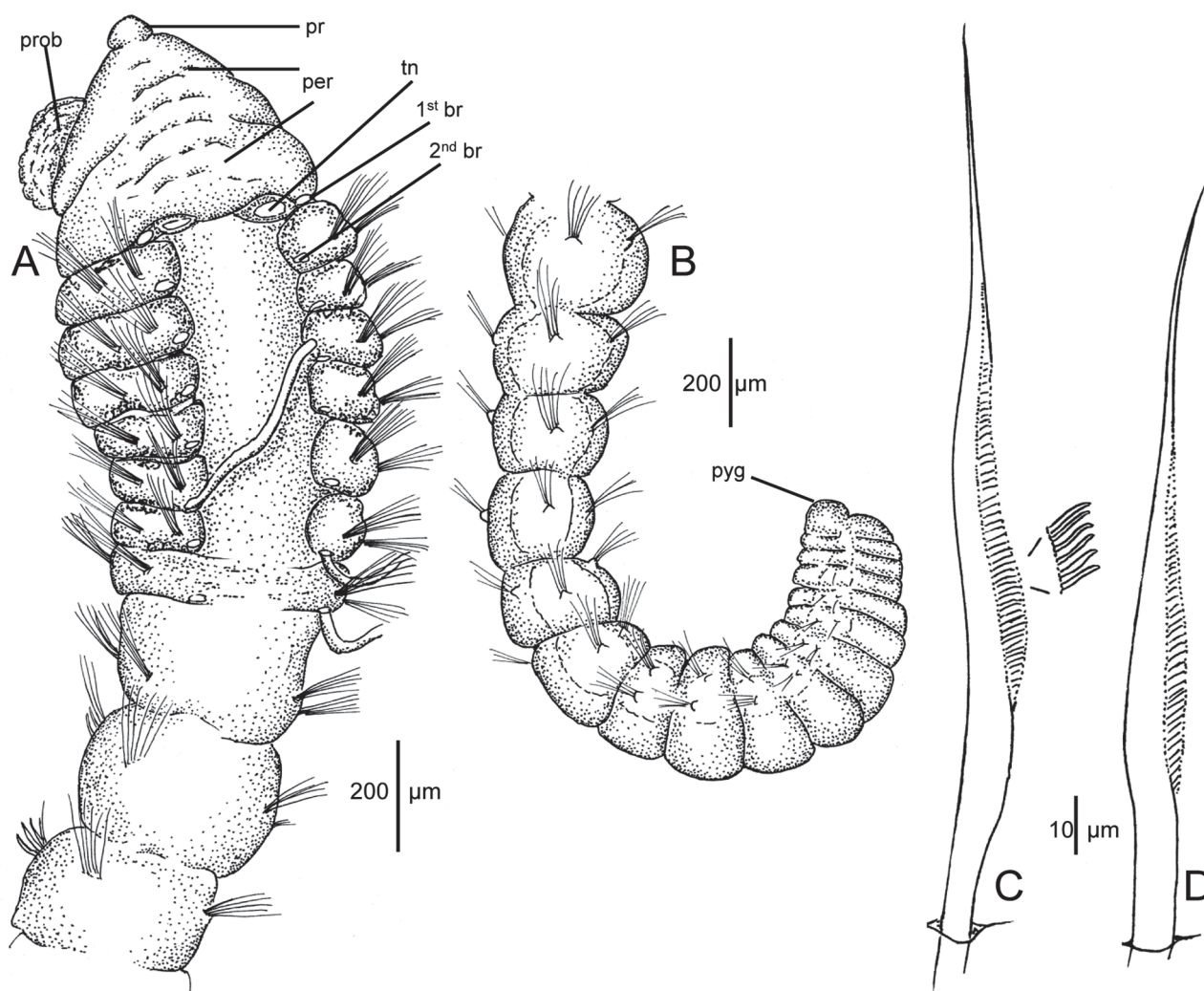


FIGURE 17. *Kirkegaardia luticastella* (Jumars, 1975): A, anterior end dorsal view; B, posterior end, right lateral view; C–D, denticulated neurosetae. (LACM-AHF Poly 8929).

The species most similar to *K. luticastella* is *K. jumarsi* **n. sp.** described in this paper from the Peru-Chile Trench. The two species are compared below in the *K. jumarsi* **n. sp.** description. A third species, *K. olgahartmanae* **n. sp.**, from off the Antarctic Peninsula is also closely related to both of these species and is treated separately below.

Biology. The species is known only from muddy sediments in offshore basins and slope depths. At the Farallons location, *K. luticastella* was found only once, and in an environment with fine silty sediments dominated by numerous polychaetes of the families Paraonidae, Spionidae, Cossuridae, and Cirratulidae (mainly species of *Chaetozone*) (Blake *et al.* 2009).

Distribution. San Diego Trough off Southern California, 1200 m in soft sediments; continental slope off northern California, 2637 m in muddy sediment.

***Kirkegaardia dutchae* new species**

Figures 18–19

Monticellina sp. N1. Welch & Dutch 2014: 9, 4 figs; Washington State Department of Ecology MSMP; database online: (PSEmpMarineBenthicSpeciesList_sortable.xlsx) online: <http://www.eopugetsound.org/species/custom-lists/306>.

Monticellina tessellata: Welch & Dutch 2014: 7–8, 6 figs. Not Hartman 1960.

Material examined. Northeastern Pacific, Puget Sound, Shoreline Elliott Bay, Sta. 181, Rep. 1, 18 June 1998,

47.61504°N, 122.36230°W, 36.7 m, coll. MSMP, 4 **paratypes** (LACM-AHF Poly 8930); Sta. 182, Rep. 1, 18 June 1998, 47.60421°N, 122.34413°W, 38.3 m, coll. MSMP, **holotype** and 4 **paratypes** (LACM-AHF Poly 8931–2); Mid Elliott Bay, Sta. 189, Rep. 1, 22 June 1998, 47.59051°N, 122.38049°W, 14.3 m, coll. MSMP, 2 **paratypes** (LACM-AHF Poly 8933); Port Gamble Bay, Sta. 213, Rep. 1, 25 June 1999, 47.82230°N, 122.57560°W, 4.7 m, 2 specimens (MSMP AN1542); Freshwater Bay, Sta. WA 1007, Rep. 1, 27 Aug. 1999, 48.14972°N, 123.60250°W, 21.6 m, 1 specimen (MSMP AN 2163); Port Orchard, St. Clair inlet, Sta. 202, Rep. 1, 12 June 2009, 47.56099°N, 122.59580°W, 3.9 m, 2 specimens (MSMP AN1957).—**Olympic Coast National Marine Sanctuary**, Washington Coastal EMAP Sta. 3-114, Rep. 1, 03 June 2003, 47.62012°N, 124.75491°W, 82.0 m, (1 long, thin **paratype** in 2 parts) (LACM-AHF Poly 8934).

Description. A slender, elongate, and threadlike species; holotype complete, 14 mm long, 0.30 mm wide across thoracic region, 0.25 mm wide across abdominal segments, with 82 setigerous segments. Thoracic region relatively narrow, with 12–14 setigerous segments (Figs. 18A, 19A, D–E); parapodia only slightly elevated forming lateral shoulders, with dorsum broad and higher than parapodia (Fig. 18A) domed, rounded in cross section. Venter of thoracic region broadly flattened, middle and posterior thoracic segments with distinct glands that appear lighter than rest of body and stain darkly with MG (Fig. 19A–B). Thoracic segments narrow, about 4.5x as wide as long, transitioning to weakly moniliform anterior abdominal segments, only 0.3x as wide as long (Fig. 18B); middle abdominal segments as long as wide, more of a block shape than oval (Fig. 18C); far posterior segments again becoming narrow, forming weakly expanded posterior end with up to 15 setigerous segments and weak ventral groove, terminating in narrow pygidium with terminal anus and a single conical ventral lobe (Figs. 18D, 19E).

Prostomium conical, tapering to rounded anterior end (Figs. 18A–B, 19C–D); eyes absent; nuchal organs narrow lateral slits at junction with peristomium (Fig. 18B). Entire pre-setigerous region elongate, narrow, 2.1x as long as wide in dorsal view, 1.5x as long as wide in lateral view; as long as first six thoracic segments (Figs. 18A, 19D). Peristomium either entirely smooth or with 1–2 lateral grooves producing 0–3 partial annular rings (Figs. 18A–B, 19C); dorsal surface with low irregular ridge extending over level of setiger 1 and merging with mid-dorsal thoracic surface. Dorsal tentacles arising from posterior margin of peristomium lateral to mid-dorsal ridge (Fig. 18A); first pair of branchiae on anterior border of setiger 1; lateral to dorsal tentacles; second pair of branchiae on posterior border of setiger 1, thus two branchiae on setiger 1 (Figs. 18A, 19C); following thoracic branchiae on posterior border of each setiger.

Parapodia shifted dorsally in thoracic segments forming distinct lateral shoulders below broadly rounded dorsal surface (Fig. 18A); abdominal parapodia located laterally. Individual noto- and neuropodia generally close together along body, each with low podial lobes from which setae emerge (Fig. 18E). Notosetae all simple, smooth capillaries throughout with fibrils and serrations not evident with light microscopy; thoracic and anterior abdominal neurosetae similar to notosetae, transitioning to shorter, broader capillaries in middle abdominal segments at about setigers 35–40; these bearing fine denticles along expanded medial margin (Fig. 18E, H–I); some transitional neurosetae of anterior abdominal segments narrow, but with a few longer denticles mid-way along shaft (Fig. 18F–G).

Methyl Green stain. Distinct transverse segmental bands across venter of thorax (Fig. 19A–B), deepest stain on 3–4 posteriormost thoracic segments; lateral intersegmental vertical bands or patches on anterior abdominal segments (Fig. 19A–B); stain not concentrated elsewhere on the body. The ventral thoracic bands correspond to the lighter colored glandular ventral surface of non-stained specimens.

Etymology. This species is named for Ms. Margaret (Maggie) Dutch, Manager of the State of Washington Puget Sound Benthic Monitoring Program and a former colleague; she provided specimens of this species and others from the MSMP reference collections.

Remarks. *Kirkegaardia dutchae* n. sp. from the northeastern Pacific is most closely related to *K. baptistae* from along the U.S. Atlantic shelf and slope in having a similar size and shape to the pre-setigerous region, parapodia limited to lateral shoulders situated lower than the broad dorsal surface, and prominent glands along the venter of thoracic segments.

The two species differ in that *K. baptistae* has ventral thoracic glands that are naturally light tan in color and do not produce a MG staining pattern of any kind, with the stain disappearing entirely in clean alcohol; however, these glands may retain pink coloration from Rose Bengal for a time after storage. In contrast, the same glands of *K. dutchae* n. sp. retain a distinct MG pattern on the venter of the thoracic region after differentiation. Additional

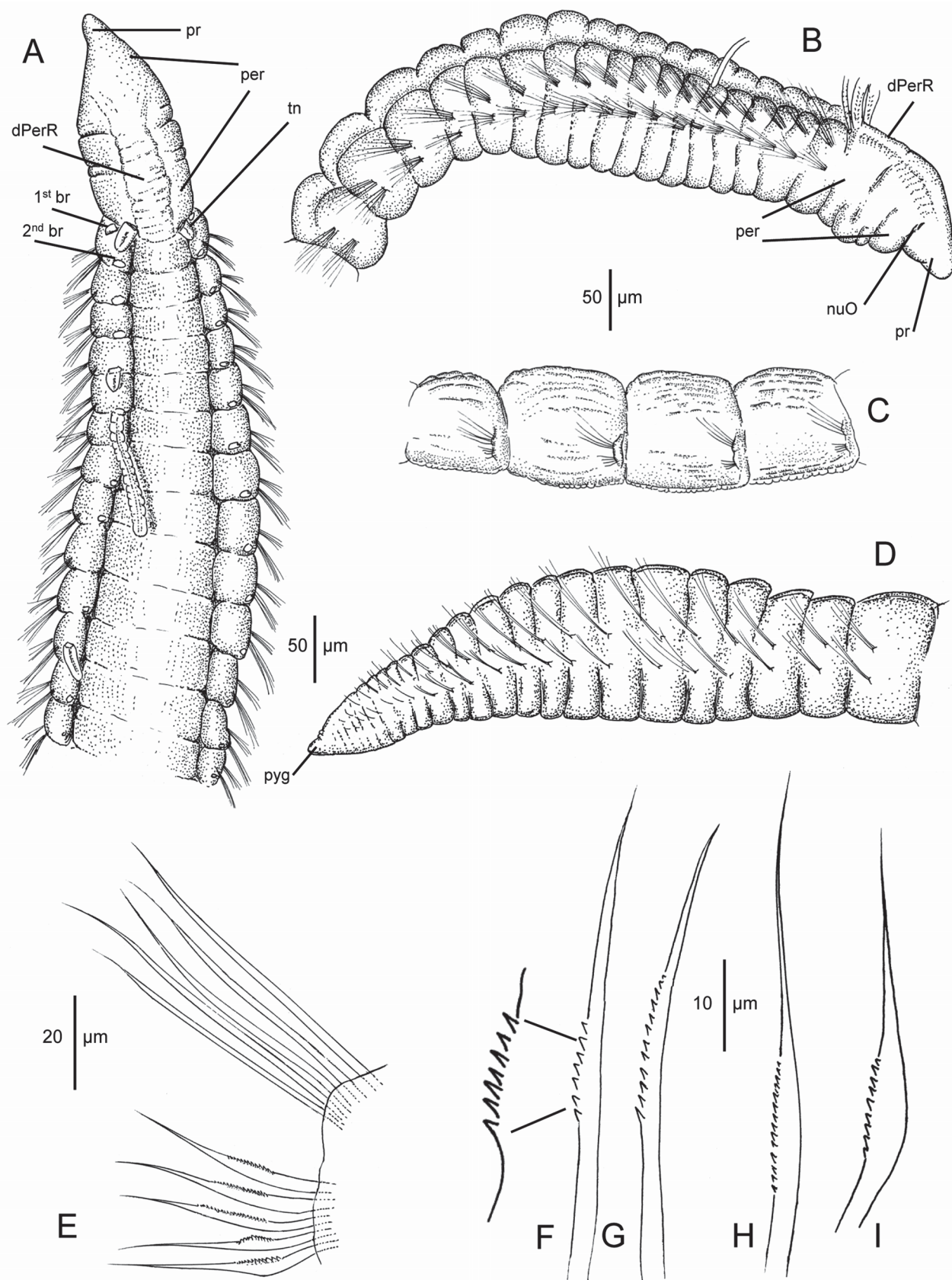


FIGURE 18. *Kirkegaardia dutchae* n. sp.: A, anterior end, dorsal view; B, anterior end, right lateral view; C, middle abdominal segments, left lateral view, anterior end toward the left; D, posterior end, right lateral view; E, anterior abdominal parapodium, anterior view; F–G, denticulate neurosetae from anterior abdominal segment; H–I, denticulate neurosetae from middle abdominal segment. A, B–I, paratypes (LACM-AHF Poly 8930); B, holotype (LACM-AHF Poly8931).

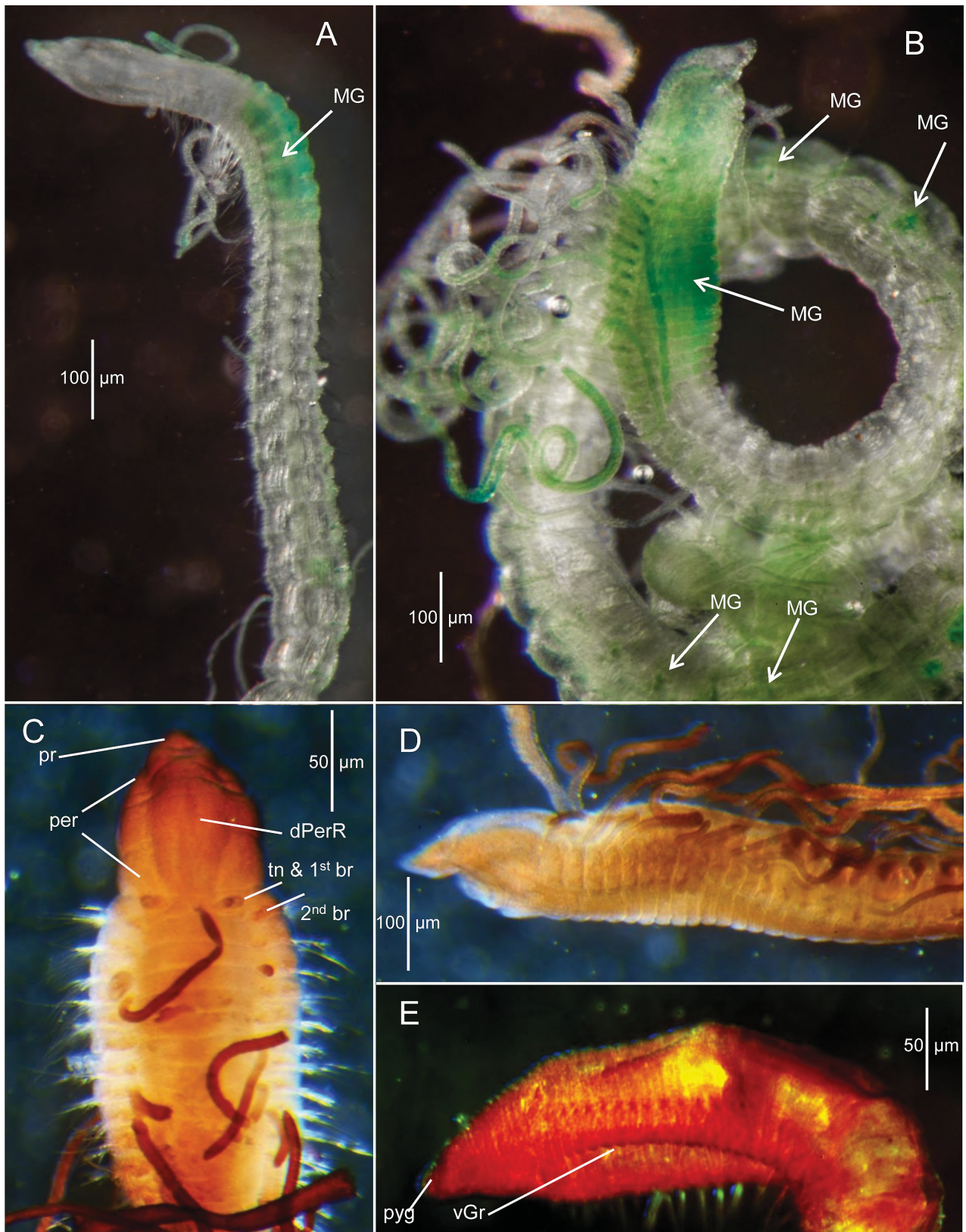


FIGURE 19. *Kirkegaardia dutchae* n. sp.: A–B, two paratypes from Sta. 182 (LACM-AHF Poly 8932) showing Methyl Green staining patterns; A, ventral view; B, right lateral view.—C–E, specimens from Sta. 202 (MSMP AN1957), stained with Shirlastain A: C, anterior end dorsal view; D, anterior end, left lateral view; E, posterior end, right lateral view.

differences include denticulated capillaries limited to neuropodia in *K. dutchae* **n. sp.** instead of both noto- and neuropodia as in *K. baptisteae*. Further, the denticles are limited to an expanded knob on the shaft of *K. dutchae* **n. sp.** whereas in *K. baptisteae* the denticles are distributed along most of the shaft. Additionally, the first and second pair of branchiae are on setiger 1 in *K. dutchae* **n. sp.**; whereas in *K. baptisteae* the first pair of branchiae are lateral to the dorsal tentacles on the posterior margin of the peristomium and only the second pair are on setiger 1. *K. dutchae* **n. sp.** is also similar to *K. tessellata*, but differs in lacking a mid-thoracic ridge. All three species, however, are now known to have tessellated tubes.

Biology. Two paratypes from Station 181, June 1998, had numerous sperm packets in the coelom; one paratype from Sta. 182 also collected in June 1998 was packed with yolky eggs having a visible germinal vesicle and measuring 96–127 μm ; a paratype from Sta. 189, also collected in June 1998, had both small oocytes ca. 20- μm diameter and larger ova 93–101 μm diameter in adjacent segments. These data suggest that gametes were not fully mature in June; it is likely spawning and recruitment occur later in the summer. The specimens from Sta. 213 were labeled *Monticellina tessellata* in the MSMP voucher collection because of the surrounding tessellated tube. However, the two specimens agree well with *Kirkegaardia dutchae* **n. sp.** and not *K. tessellata* because a peristomial ridge is present and a mid-thoracic ridge is absent instead of absent and present, respectively, as in *K. tessellata* (Blake 1996). *Kirkegaardia dutchae* **n. sp.** is herein recognized as one of several closely related species having the tattered or tessellated tubes first reported for *K. tessellata*, a California species.

Distribution. Known only from the Puget Sound in shallow depths, 14–82 m.

Kirkegaardia cristata new species

Figure 20

Material Examined. Northeastern Pacific, Puget Sound, Case Inlet, Sta. 47, Rep. 1, 01 April 1993, 47.23300°N, 122.84984°W, 20 m, coll. MSMP, **holotype** (LACM-AHF Poly 8935).

Description. Holotype only specimen, mostly complete, 7.25 mm long, 0.4 mm wide across thorax, with 60 setigerous segments. Color in alcohol, light tan.

A slender, threadlike species, with narrow, tapering pre-setigerous region and thoracic region only slightly wider than peristomium (Fig. 20A). Pre-setigerous region 1.6x as long as wide; as long as first 13 thoracic setigers (Fig. 20A). Prostomium triangular, tapering to narrow rounded apex (Fig. 20A); eyes absent; slit-like nuchal organs present on posterior lateral margins. Peristomium only slightly longer than wide; smooth with three lateral grooves posterior to prostomium producing four weakly developed annulations (Fig. 20A); prominent dorsal ridge extending along peristomium from posterior margin of prostomium to posterior end of peristomium, then continuing as narrow bead-like ridge within mid-dorsal thoracic channel (Fig. 20A). Dorsal tentacles on posterior margin of peristomium; first pair of branchiae lateral to tentacles between peristomium and anterior border of setiger 1 (Fig. 20A); second pair of branchiae on setiger 1 dorsal to notosetae on posterior margin of segment overlying mid-dorsal channel; subsequent thoracic branchiae in same location (Fig. 20A); anterior abdominal branchiae mostly missing, but appear to also be located on dorsum.

Thoracic region with 14–15 setigers, all narrow, first 10 thoracic setigers crowded, 11x wider than long, next five setigers 7x wider than long (Fig. 20A). Subsequent anterior and middle abdominal setigers longer, 2.1x as wide as long (Fig. 20B); posterior abdominal setigers becoming oval, moniliform (Fig. 20C); last 1–2 narrow; pygidial segment absent. Thoracic region with venter swollen, rounded; anterior abdominal segments with prominent ventral groove; groove absent in posterior abdominal segments. Thoracic region with parapodia dorsally elevated overlying mid-dorsal channel continuing as narrow dorsal ridge (Fig. 20A).

Dorsally elevated parapodia of thoracic region shifting to lateral position in abdominal segments (Fig. 20B–C). Parapodia narrow ridges from which setae project; thoracic setae consisting of long simple capillaries with smooth margins, numbering 6–7 per notopodium and 8–9 per neuropodium; anterior abdominal setae similar but fewer in number with 4–5 in both noto- and neuropodia; neurosetae becoming shorter and broader; setae of posterior abdominal segments increasing to 5–6 in notopodia and 6–8 in neuropodia; denticulate noto- and neurosetae observed only with light microscopy in posterior abdominal setigers from about setiger 45 with denticles visible at 400x. Denticles of noto- and neurosetae similar, short, minutely pointed (Fig. 20D–E). Denticles of notosetae directed ventrally, with denticles of neurosetae directed dorsally, *vis-à-vis*.

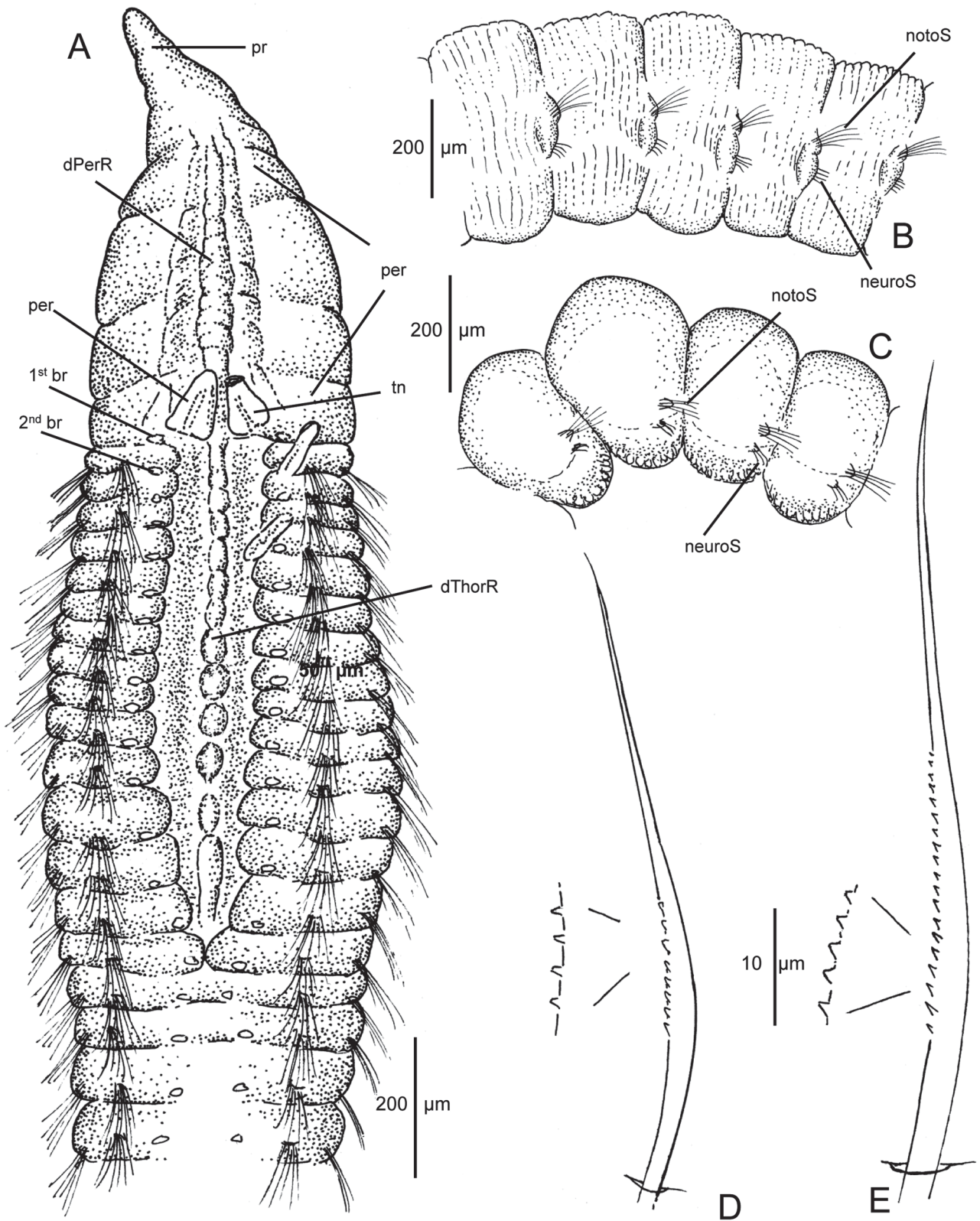


FIGURE 20. *Kirkegaardia cristata* n. sp., holotype (LACM-AHF Poly8935): A, anterior end, dorsal view; B, middle abdominal segments, left lateral view; C, far posterior segments, left lateral view; D, neuroseta; E, notoseta.

Methyl Green stain. Ventral surface of last 5–6 thoracic segments staining intensely as a large patch.

Etymology. From the Latin, *crista*, for crest or ridge, referring to the mid-dorsal ridge or keel that starts on the peristomium and continues within the mid-dorsal channel.

Remarks. *Kirkegaardia cristata* n. sp. belongs to a large group of 12 species that have the parapodia dorsally elevated and overlying a distinct mid-dorsal channel. Within this group, *K. cristata* n. sp. belongs to a smaller subgroup including *K. annulosa*, *K. kladara* n. sp., and *K. hamptoni* n. sp. that have a mid-dorsal ridge along the entire mid-line of the peristomium. *K. cristata* n. sp. differs from all of these species in having four distinct annular rings on the peristomium instead of 0–2. In addition, *K. kladara* n. sp. has the first branchiae arising from setiger 1 instead of posterolateral to the tentacular cirri on the peristomium as in *K. cristata* n. sp. and the other two species. Although all four species have a prominent MG pattern on the venter of the peristomium, *K. annulosa* and *K. hamptoni* n. sp. have patches of stain on the peristomium that is entirely lacking in both *K. cristata* n. sp. and *K. kladara* n. sp.

Distribution. Known only from the Puget Sound, Washington, in ca. 20 m.

***Kirkegaardia franciscana* new species**

Figures 21–22

Monticellina sp. 2: Hilbig & Blake 2006: 262; Blake *et al.* 2009: 1796.

Material examined. California continental slope west of the Farallon Islands, San Francisco Deep Ocean Disposal Site (SF-DODS) 2003 monitoring survey, R/V *Point Sur*, Sta. 19, 37°37.97'N, 123°30.04'W, 2983 m, 24 September 2003, coll. J.A. Blake, **holotype** and 3 **paratypes** (LACM-AHF Poly 8921–2); 2004 monitoring survey, R/V *Point Sur*, Sta. 52, 37°44.00'N, 123°28.00'W, 2237 m, 03 October 2004, coll. J.A. Blake, 3 **paratypes** (LACM-AHF Poly 8923).

Description. A small, elongate, threadlike species (Figs. 21A–B, 22A); holotype complete, 1.5 mm long, 0.11 mm wide for 26 setigerous segments; most paratypes complete, similar in size and number of segments. Color in alcohol opaque white; no pigment present.

Pre-setigerous region about 1.5x as long as wide; prostomium a conical lobe, narrowing to rounded tip (Figs. 21A, 22A–D); eyes absent; nuchal organs observed in two paratypes as darkly pigmented areas at posterolateral margins (Fig. 22C). Peristomium expanded, relatively smooth, with one partial lateral groove, but no distinct annulations (Fig. 21A); dorsally with two narrow longitudinal grooves outlining a smooth, curved, broad dorsal surface with a weak narrow crest (Fig. 21A). Dorsal tentacles inserted at posterolateral margins of peristomium, more widely separated than in related species. First pair of branchiae lateral to tentacles on peristomium; second pair of branchiae on posterior margin of setiger 1, dorsal to notosetae; subsequent branchiae in similar positions (Fig. 21A).

Thorax with 4–6 narrow segments about 2x as wide as long; parapodia not elevated over dorsum as in many related species; dorsal surface not enclosed in a groove formed by parapodia; thoracic segments abruptly transitioning to abdominal segments that are as long as wide (Figs. 21A, 22A–D), then becoming longer than wide (Fig. 21B), some moniliform 1.5x as long as wide (Figs. 21B, 22A–D); far posterior segments narrowing to pygidium with a single lobe (Figs. 21B, 22A).

Parapodia reduced to simple conical lobes from which setae emerge. Thoracic and anterior abdominal parapodia with simple capillary setae only; middle and posterior abdominal neurosetae becoming shorter, broader, and with fine denticles along one edge at about setiger 30 (Fig. 21C), these best observed with 1000x magnification and with Phase Contrast optics; individual denticles short, pointed toward apex of seta. Some abdominal notosetae observed with long stiff fibrils or serrations along one edge (Fig. 21D), these very regular in appearance.

Methyl Green stain. A spectacular MG staining pattern characterizes this species. The prostomium and lateral and dorsal sides of the peristomium develop a deep reticulated turquoise pattern followed by similar staining on the ventral and lateral sides of the thoracic parapodia (Fig. 22D); the two longitudinal grooves on either side of the peristomium stain a deep green; the thoracic parapodia are in effect banded (Fig. 22D). The reticulated pattern is due to embedded glands that are also stained by MG on most abdominal segments although being sparse; the pattern is not as intense as on anterior segments.

Etymology. The name *franciscana* refers to the proximity to the City of San Francisco of the sampling site, the San Francisco Deep Ocean Disposal Site.

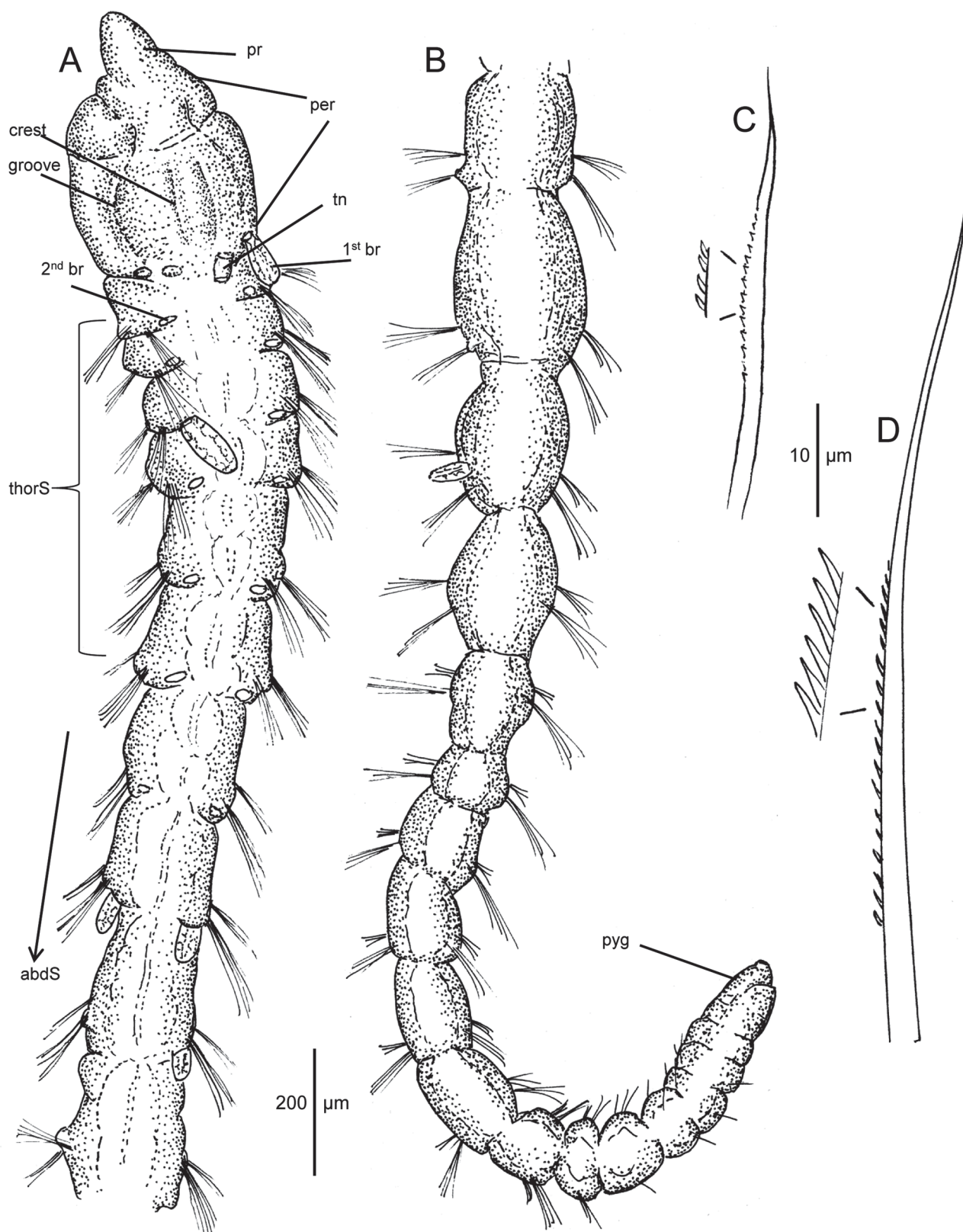


FIGURE 21. *Kirkegaardia franciscana* n. sp., holotype (LACM-AHF Poly 8921): A, anterior end, dorsal view; B, posterior end, dorsal view; C, denticulate neuroseta; D, serrated notoseta.

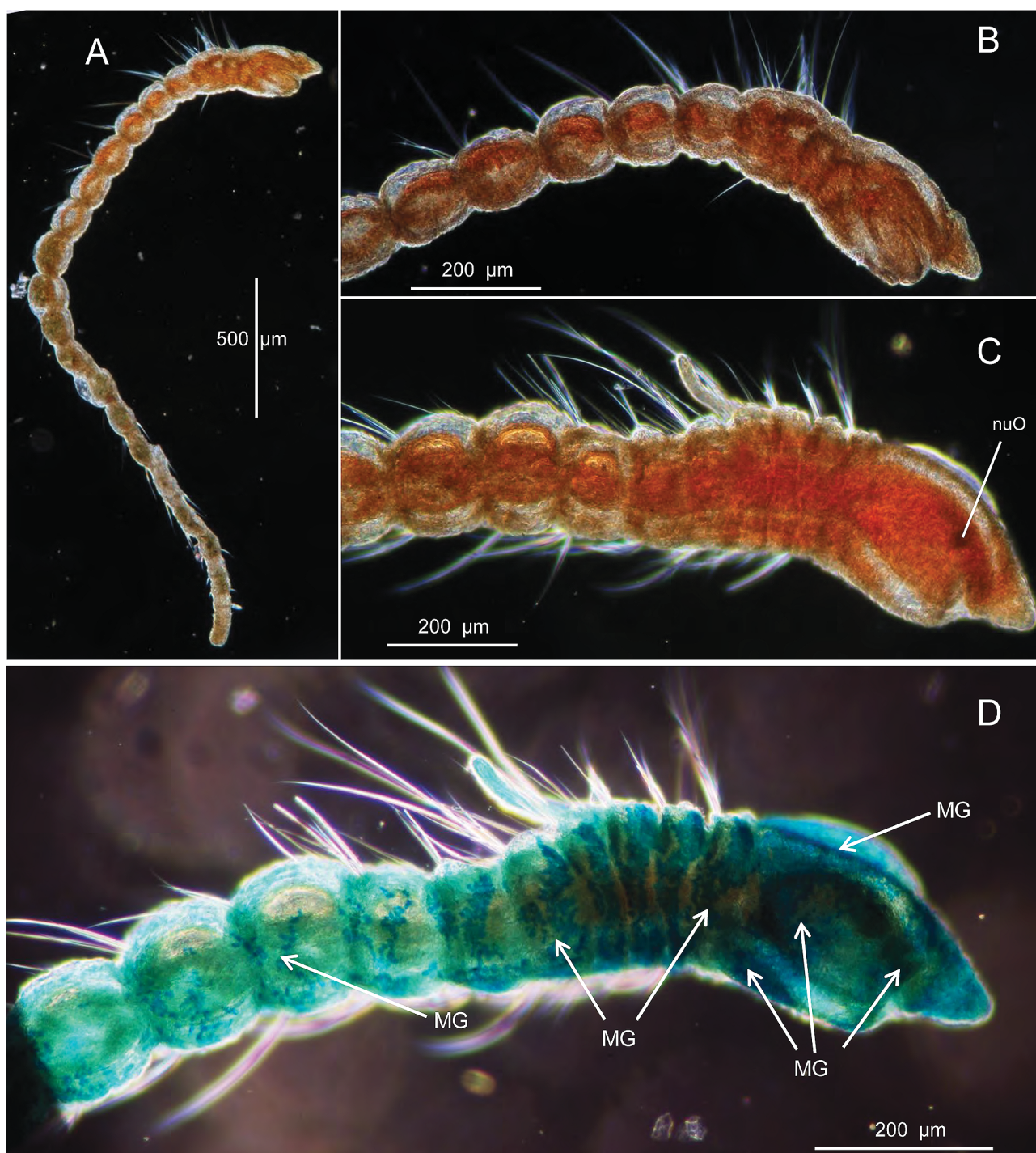


FIGURE 22. *Kirkegaardia franciscana* n. sp., paratypes (LACM-AHF Poly 8922): A, entire worm, right lateral view; B, same specimen, anterior end; C, anterior end, right lateral view of another specimen; D, same with Methyl Green staining patterns. A–C, stained with Shirlastain A; D, with Methyl Green.

Remarks. *Kirkegaardia franciscana* n. sp. is a unique species in the very small size, expanded and rounded shape of the anterior end, narrow abdominal region with moniliform segments, and the distinctive MG staining pattern. The denticulated neurosetae are few, usually no more than two or three per abdominal neuropodium and with the fine denticles observed only with at least 1000x magnification. The serrated notosetae are also few and observed only with 1000x. The long pointed serrations of these setae were initially thought to be merely splayed fibrils sometimes observed on capillaries of other cirratulids. However, the regularity and consistent size of these serrations finally suggested they were a consistent type of tooth or denticle. It needs to be stated, however, that none of these specimens were sexually mature and it is entirely possible that they are juveniles. In a program

during which more than 180 quantitative benthic samples were collected over a period of 13 years, *K. franciscana* **n. sp.** was rare, identified only three times, and either larger adults were never collected or were not recognized. The MG pattern was used to set them aside for further study resulting in this description as a new species. In checking other cirratulids from the study that are larger and might overlap with the morphology of smaller specimens of *K. franciscana* **n. sp.**, two species of *Aphelochaeta* were described by Doner & Blake (2009); only one of which had a MG pattern and it was entirely different from that of *K. franciscana*. Other species of *Aphelochaeta* are also known from this area (Blake unpublished); none of these has a MG pattern as distinctive as that of *K. franciscana*. *Kirkegaardia carinata* **n. sp.** occurs throughout the study area and also has a distinctive, but different MG staining pattern and a very different morphology (see below).

Biology. *Kirkegaardia franciscana* was collected only rarely over 13 years of monitoring at the San Francisco Deep-water Disposal site. The sediments where the species was collected are composed of fine silt. Throughout the study area the benthic fauna is dominated by a large suite of polychaetes of the families Paraonidae, Spionidae, Cossuridae, and cirratulids of the genus *Chaetozone*, most of which were described by Blake (2006). Ecology of the site was reported by Blake *et al.* (2009).

Distribution. Known only from lower slope depths off northern California 2237–2983 m.
Figures 21 and 22 about here

Kirkegaardia carinata new species

Figures 23–24

Monticellina sp. 3: Blake *et al.* 2009: 1796.

Material examined. California continental slope west of the Farallon Islands, San Francisco Deep Ocean Disposal Site (SF-DODS): 2003 monitoring survey, R/V *Point Sur*, Sta. 116, 37°35.080'N, 123°29.039'W, 2908 m, 13 July 2007, coll. J.A. Blake, **holotype** (LACM-AHF Poly 8928); Sta. 23, 37°36.860'N, 123°28.850'W, 24 September 2003, 2821 m, coll. J.A. Blake, 1 **paratype** (LACM-AHF Poly 8924); 2006 monitoring survey, R/V *Point Sur*, Sta. 64, 37°35.968'N, 123°32.989'W, 3145 m, 27 September 2006, coll. J.A. Blake, 1 **paratype** (LACM-AHF Poly 8925); Sta. DR2A, 37°22.924'N, 124°01.001'W, 3775 m, 29 July 2006, coll. J.A. Blake, 1 **paratype** (LACM-AHF Poly 8926); 2007 monitoring survey, R/V *Point Sur*, Sta. 19, 37°38.166'N, 123°30.213'W, 3100 m, 11 July 2007, 1 **paratype** (LACM-AHF Poly 8927); Sta. DR3A, 37°17.537'N, 124°09.192'W, 3864 m, 13 July 2007, 1 specimen, coll. J.A. Blake (JAB).

Description. An elongate, narrow-bodied species, all specimens incomplete. Holotype mostly complete, 17 mm long, 0.5 mm wide across thoracic region, with 71 setigerous segments; paratypes smaller, with fewer segments; length and number of setigerous segments variable, age dependent. Thoracic region with 10–12 setigerous segments, with slender, less mature specimens having fewest. Thoracic segments about 2x as wide as long (Figs. 23A, 24A–B), transitioning to anterior abdominal segments only slightly wider than long with segmental boundaries indistinct (Figs. 23C, 24C); middle and posterior segments becoming oval, but not moniliform; no ventral grooves or ridges present; thin ventral line evident along abdominal segments, not a raised ridge.

Pre-setigerous region about 1.8x as long as wide. Prostomium conical, tapering to narrow rounded apex (Figs. 23A–B, 24A–B); eyes absent; slit-like nuchal organs present on posterior lateral margins (Fig. 23B). Peristomium smooth without obvious annulations, dorsal surface raised, but without an obvious crest (Figs. 23A–B, 24A–B), peristomium merging posteriorly with raised mid-dorsal ridge of thoracic region (Fig. 23A). Dorsal tentacles arising on posterior margin of peristomium, with first pair of branchiae posterolateral to tentacles in notch between peristomium and setiger 1 (Fig. 23A–B); second pair of branchiae on posterior margin of setiger one dorsal to notosetae and on edge of mid-dorsal channel (Fig. 23A); subsequent thoracic branchiae in similar location; anterior abdominal branchiae, when present dorsal to notosetae, but not in as dorsal a position because parapodia shift laterally; no branchiae observed in middle and posterior segments.

Parapodia of thoracic region elevated above dorsal midline, producing shallow mid-dorsal channel or groove between parapodia (Fig. 23A); this channel with narrow elevated ridge or keel continuing to end of thoracic region; ridge broken into elevated lobes in last 2–3 thoracic segments (Fig. 23A).

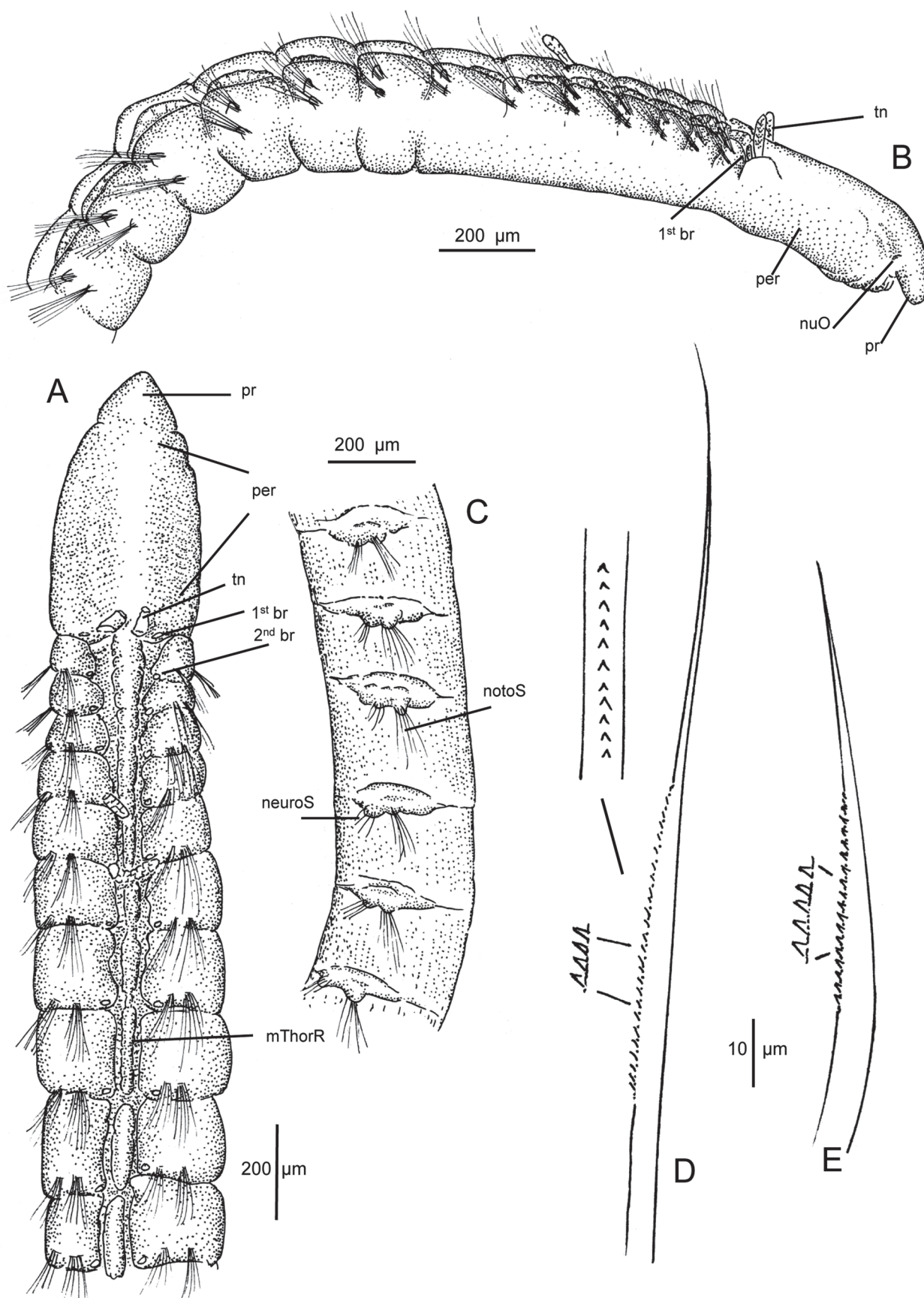


FIGURE 23. *Kirkegaardia carinata* n. sp., holotype (LACM-AHF Poly8928): A, anterior end, dorsal view; B, anterior end, right lateral view; C, middle abdominal segments in left lateral view; D, denticulate notoseta with two insets (not to scale); E, neuroseta with inset (not to scale).

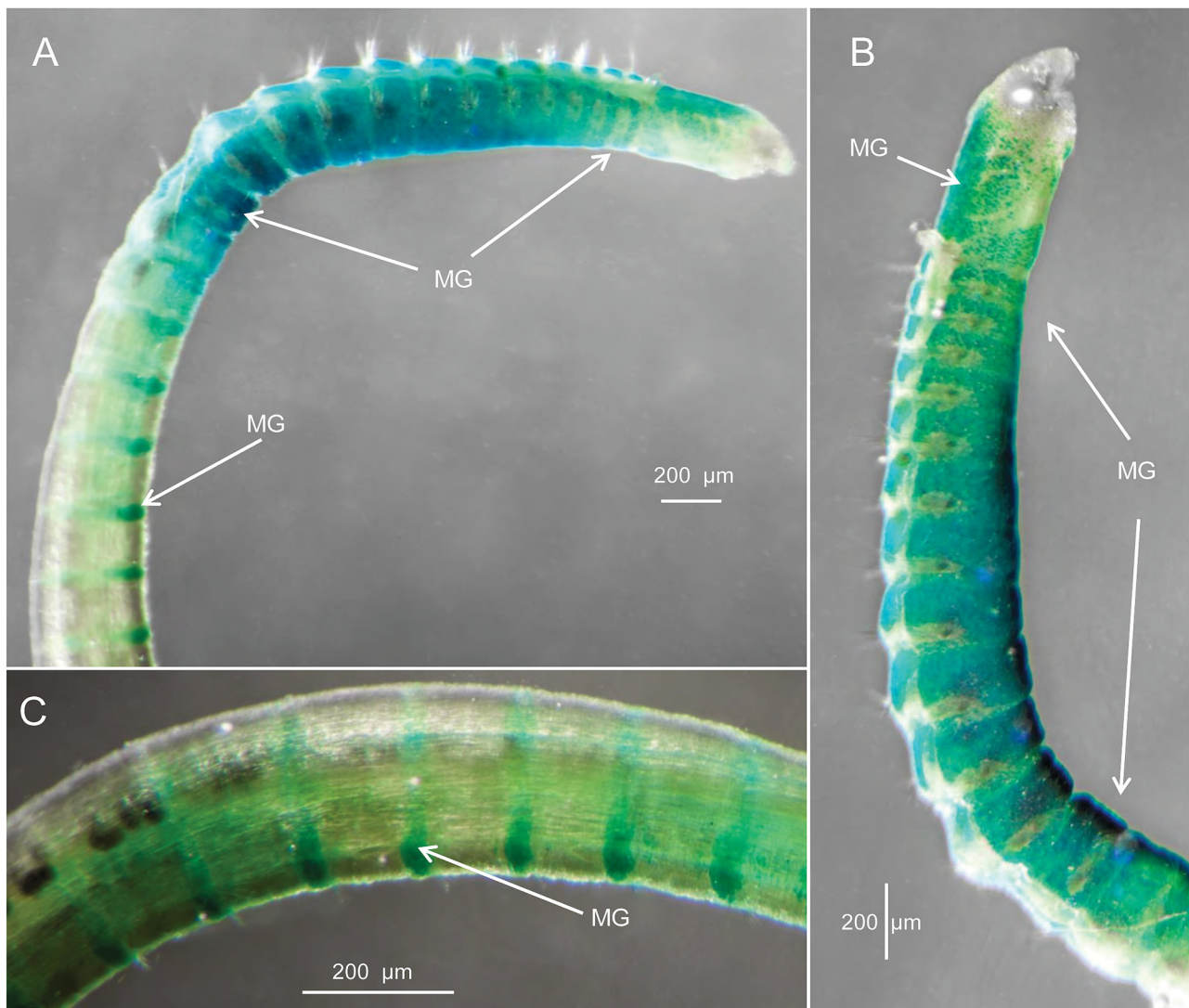


FIGURE 24. *Kirkegaardia carinata* n. sp. holotype (LACM-AHF Poly 8928) stained with methyl green: A, anterior end, right lateral view; B, same, closer view; C, anterior abdominal segments.

Parapodia well-developed throughout, with short triangular-shaped podial lobes in thoracic region and broad membranous parapodia in abdominal segments (Fig. 23A); abdominal parapodia surrounded by dark glandular tissue that retains MG stain imparting distinctive pattern along entire body (Fig. 24C, see below). Thoracic setae consisting of 11–12 long simple capillaries per notopodium and 8–10 similar setae per neuropodium; anterior abdominal setae similar with neurosetae becoming shorter, wider basally, and with minute denticles along one edge from setigers 16–17 on holotype visible at 400–1000x (Fig. 23E); notosetae also developing denticles along one edge from setigers 17–18 on holotype (Fig. 23D). Noto- and neurosetae numbering 5–6 per notopodium in anterior abdominal parapodia and 4–5 in posterior parapodia; neurosetae shorter and broader than notosetae, numbering up to 10 per neuropodium in anterior abdominal segments and 4–5 in posterior abdominal segments. Noto- and neurosetae of abdominal segments with fine denticles or teeth along one margin (Fig. 21D–E). Noto- and neurosetae with denticles directed ventrally and denticles of neurosetae directed dorsally, *vis-à-vis*.

Nature of posterior end and pygidium not known.

Methyl Green stain. *Kirkegaardia carinata* n. sp. has a distinctive MG staining pattern, with the holotype having a mid-dorsal elongate oval patch on the peristomium that extends somewhat laterally (Fig. 24A–B); the venter of thoracic region has dark-blue-staining segmental bands that extend dorsally to the mid-dorsal ridge (Fig. 24A–B); the parapodia of abdominal segments stain heavily producing lateral lines along each segment (Fig. 24C).

Etymology. The species name, *carinata* is from the Latin *carina*, a keel, referring to the mid-dorsal ridge that is within the channel between the parapodia of the thoracic region of this species.

Remarks. *Kirkegaardia carinata* n. sp. is another species in the group of 12 species that have the thoracic parapodia elevated over a mid-thoracic channel. Of these 12 species, *K. carinata* n. sp. is most similar in morphology to *K. dorsobranchialis*, *K. chilensis* n. sp., and *K. cryptica* in having an entirely smooth peristomium with no dorsal ridge. Of these, *K. carinata* n. sp. and *K. chilensis* n. sp. have a prominent mid-dorsal ridge within the dorsal channel on the thorax that is lacking in both *K. dorsobranchialis* and *K. cryptica*. *K. carinata* n. sp. differs from *K. chilensis* n. sp. in having a distinctively rich MG staining pattern on the peristomium, thoracic region, and the abdominal parapodia whereas a MG pattern is largely absent on *K. chilensis* n. sp. except for weak retention on the thoracic segments. In addition, the mid-ventral segments of the thoracic region of *K. chilensis* n. sp. are expanded whereas the thoracic segments of *K. carinata* n. sp. are all of the same size.

Biology. A rare species, *K. carinata* n. sp. is limited to lower continental slope and abyssal depths in soft muddy sediments. Some paratypes partially covered with thin crust of silt particles, suggesting a thin sediment tube may be present.

Distribution. Lower continental slope and continental rise off northern California, 2821–3864 m.

Kirkegaardia fragilis new species

Figure 25

Material examined. North equatorial Pacific Ocean, abyssal plain, Clarion-Clipperton Fracture Zone, NOAA BIE Sta. DDT-07-94, 12°55.023'N, 128°35.451'W, 0.25 m² box core, 4879 m, 29 July 1994, coll. D.T. Trueblood, **holotype** and 2 **paratypes** (USNM 1407165–6); Sta. 02-93, 12°56.166'N, 128°35.520'W, 4869 m, coll. 10 August 1993, fragments and tessellated tubes (JAB); Sta. 06-93, 12°55.780'N, 128°35.881'W, 4858 m, coll. 01 September 1993, 1 posterior fragment (JAB).

Description. A small fragile species with elongate, narrow body, cylindrical throughout; without dorsal or ventral grooves. Holotype in two parts, collectively measuring 4.2 mm long, 0.17 mm wide across thoracic segments, with 40 setigerous segments. One paratype a larger anterior fragment, 0.3 mm wide, 2.1 mm long, with 12 setigerous segments. Color in alcohol opaque white; largest paratype with black pigment spots on ventrolateral sides of peristomium and anterior margin of setiger 1.

Pre-setigerous region of holotype elongate, 1.7x as long as wide and as long as first four setigerous segments; prostomium conical, tapering to narrow, rounded apex (Fig. 25A); eyes absent; nuchal organs not observed. Peristomium relatively smooth, with thin lateral lines suggesting 2–3 annulations, but these not distinct; no achaetous segments evident (Fig. 25A). Setiger 1 distinct from peristomium. Dorsal tentacles arise near posterior end of peristomium, with one intact tentacle present on holotype (Fig. 25A); first pair of branchiae on setiger 1, dorsal to notosetae (Fig. 25A); holotype with one branchia retained on setiger 5; other branchiae identified by scars when stained with Shirlastain A (Fig. 25A). Branchiae located dorsal to notosetae throughout.

Thoracic region of holotype with five segments, each about 3.5x as wide as long (Fig. 25A); paratypes with 5–7 thoracic segments of similar proportions. Transition to long narrow abdominal region abrupt, with first segments as long as wide, becoming beadlike in middle abdominal segments, about 1.3x as long as wide (Fig. 25B); posterior abdominal segments less bead-like, transitioning to short far posterior region with about eight segments becoming weakly expanded, flattened ventrally, terminating in narrow, elongate, conical, unsegmented pygidial lobe (Fig. 25C).

Parapodia low mounds, shifted somewhat dorsal in thoracic segments and first few abdominal segments, thereafter lateral (Fig. 25B). Setae all capillaries, consisting of narrow setae with smooth blades in thoracic segments and shorter setae with broad base tapering to narrow capillary tip, with fine denticles along one edge of expanded base in middle and posterior segments, denticles not evident along narrow apex; denticles present on both noto- and neurosetae from about setiger 20, or middle of body; denticles not visible on capillaries of last 4–5 setigers. Denticles weakly visible at 400x, best observed at 1000x; individual denticles numerous, with sharp points directed basally (Fig. 25D); notosetae with denticles directed ventrally and denticles of neurosetae directed dorsally, *vis-à-vis*. Setae numbering 6–8 in both noto- and neuropodia in thoracic segments, 5–7 in middle body segments; and 4–5 in posterior segments.

Methyl Green stain. Prostomium staining light green, rest of body not retaining stain after differentiation.

Etymology. The species name *fragilis*, is from Latin, and refers to the narrow fragile nature of this species.

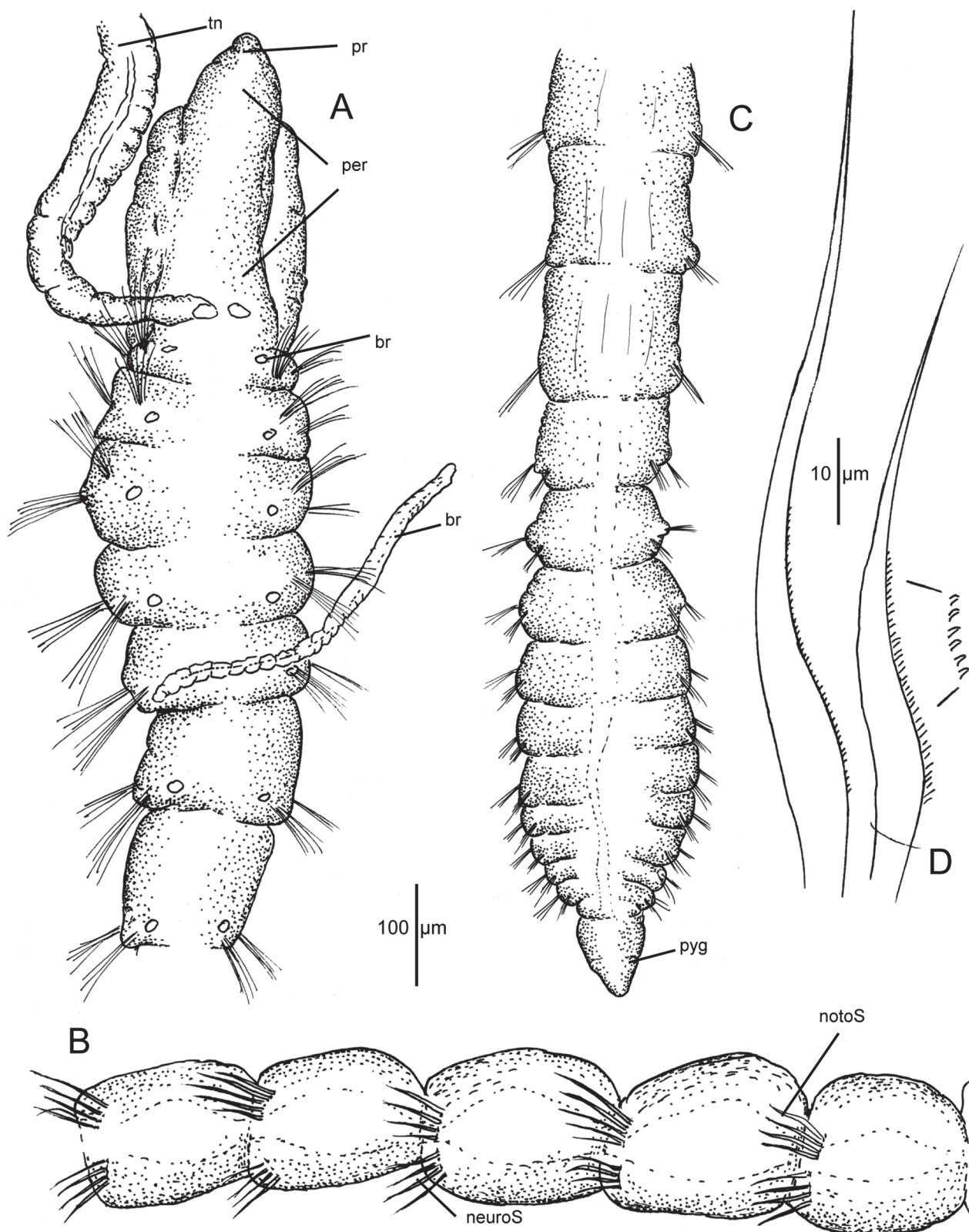


FIGURE 25. *Kirkegaardia fragilis* n. sp. holotype (USNM 1407165): A, anterior end, dorsal view; B, middle abdominal segments, right lateral view; C, posterior end with pygidium, dorsal view; D, denticulated neurosetae with inset (not to scale).

Remarks. *Kirkegaardia fragilis* belongs to a group of species in which the parapodia are not elevated over the dorsum of the thoracic region and no dorsal groove is produced; further, the first pair of branchiae occur on setiger 1 and, apart from some retention of stain on the prostomium, there is effectively no distinctive MG staining pattern for this species.

This species has no close congeners except perhaps *K. carolina* **n. sp.**, which is another small, threadlike deep-water species that occurs in upper slope depths off North Carolina and that also has tessellated tubes and branchiae from setiger 1. *K. fragilis* **n. sp.** differs from *K. carolina* **n. sp.** in having instead of lacking denticulate notosetae, in lacking instead of having annular rings on the peristomium, and by having a more expanded posterior end.

Biology. The type specimens were isolated from the 0–2 mm profile of 10-cm subcores from the box core, suggesting that this species inhabits sediments near the surface. Thin membranous tessellated tubes were found with non-type specimens in a sample from Sta. 2-93 suggesting that this species extends its branchiae into the overlying water from within the tube. The holotype is a male with sperm packets in the coelom that contain numerous sperm with small rounded nuclei.

Distribution. Known only from the Pacific Ocean in abyssal depths 4858–4879 m.

***Kirkegaardia tessellata* (Hartman, 1960) new combination**

Figure 26A–B

Tharyx tessellata Hartman, 1960: 126–127, pl. 11, figs. 1–4; 1961: 113; 1963: 53–54; 1969: 267–268, figs. 1–4.

Monticellina tessellata: Blake 1996: 328–329, figs. 8.27A–F; Imajima 1997: 198; 2001: 80–81; 2009: 122.

Material examined. California, Western Santa Barbara Channel, MMS Phase I Sta. 086, 05 Nov 1983, 34°24.45'N, 120°17.02'W, 197 m, 1 specimen (LACM-AHF Poly 8942).—West of Point Conception, MMS Phase I Sta. 073, 03 Nov 1983, 34°28.21'N, 120°36.80'W, 98 m, 1 specimen (LACM-AHF Poly 8943).—off Half Moon Bay, Sta. 2-5, R/V *Point Sur*, USEPA 102 Site Selection survey, Sta. 2-5, 37°27.96'N; 122°45.73'W, 83 m, 23 Sep 1991, coll. J.A. Blake, Chief Scientist, 1 specimen (LACM-AHF Poly 8936).

Remarks. These three well-preserved specimens agree well with the redescription of the species by Blake (1996). The two MMS Phase I specimens are from the same collections that were the basis of the MMS Taxonomic Atlas project, but were not included in the original materials examined by Blake (1996). The specimen from off Half Moon Bay confirms that the range of the species extends into northern California.

Kirkegaardia tessellata was the first cirratulid to be reported with tattered or tessellated tubes where a thick membranous material covers the worm and has lateral extensions through which groups of branchiae project (Hartman 1960; Blake 1996). The specimen from Sta. 2-5 is an exceptionally good example of this. It is important to note that the tube material of *K. tessellata* is soft, pliable (Fig. 26A) and easily removed. In contrast, the tube material described earlier in this paper for *K. neotessellata* **n. sp.** from off New England and *Kirkegaardia* sp. A from the Mediterranean Sea is different in that it is hardened and of a tough texture making it difficult to remove from the worms without considerable damage. Further, the worms themselves are distorted by the closely adhering tube upon preservation (see Fig. 15A–C for *K. neotessellata* **n. sp.** and Fig. 15D for *Kirkegaardia* sp. A). Specimens of *K. tessellata* are not distorted after preservation and removal from their tubes (Fig. 26B). Other species reported with soft-textured tessellated tubes in this study similar to *K. tessellata* are *K. antonbruunae* **n. sp.**, *K. baptistae*, *K. carolina* **n. sp.**, *K. dutchae* **n. sp.**, and *K. fragilis* **n. sp.** It is likely that other species of *Kirkegaardia* have tubes of this nature, but are not yet reported. In agreement with Blake (1996), none of these three specimens of *K. tessellata* retained any MG.

Records of *Monticellina tessellata* from deep-water in the Gulf of California, Mexico by Méndez (2007) are considerably deeper than previously recorded for the species and need to be re-examined. Records from Japan by Imajima (1997, 2001, and 2009) are likely valid, but given the results of this study, should also be re-examined.

Distribution. Off California in shelf and upper slope depths, 70–550 m.

Species of *Kirkegaardia* from the Pacific Ocean off Western South America

***Kirkegaardia giribeti* (Dean & Blake, 2009) new combination**

Figure 26C

Monticellina giribeti Dean & Blake 2009: 116–117, Figs. 6B, 8A–F.

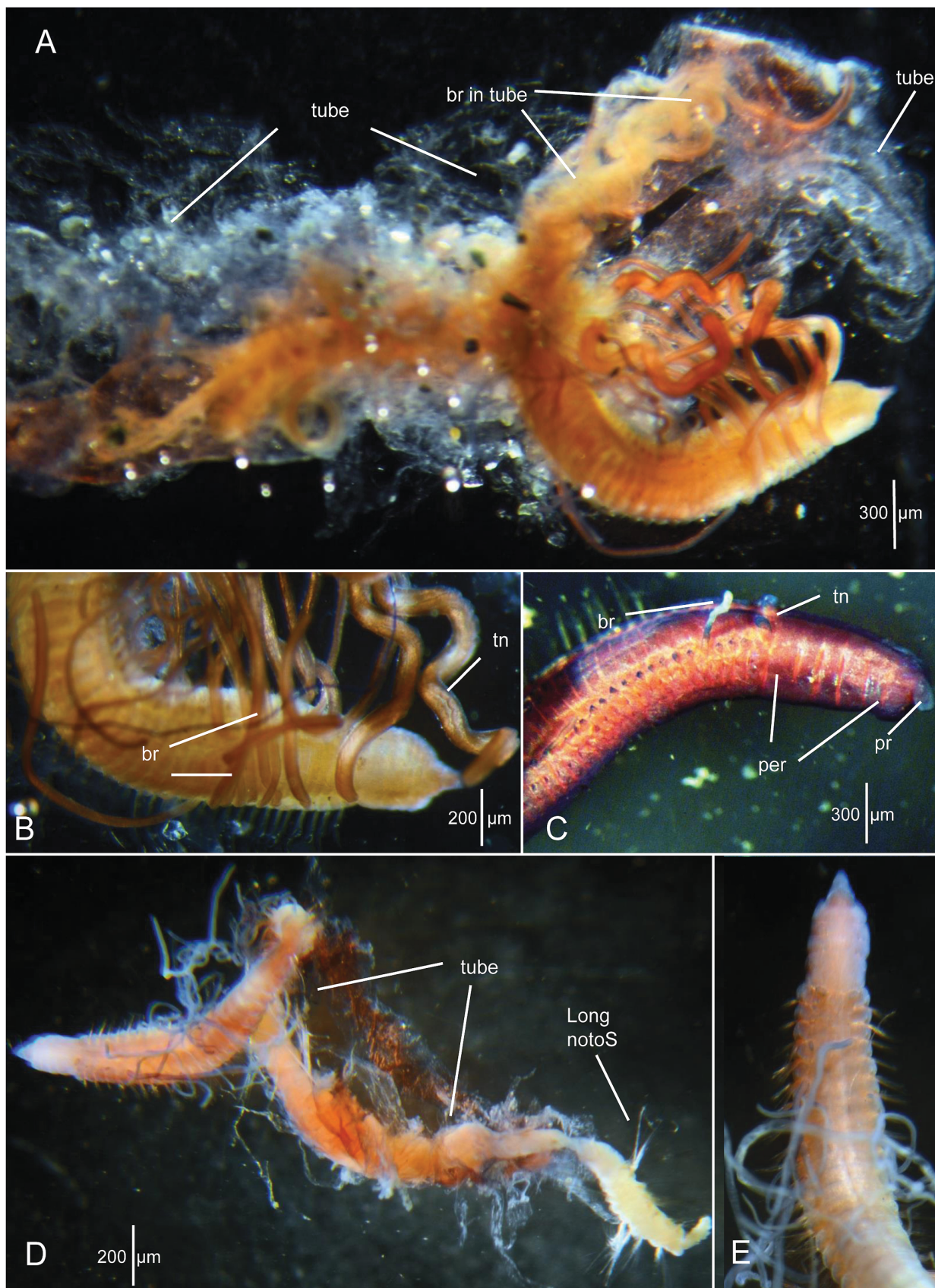


FIGURE 26. A–B, *Kirkegaardia tessellata* (Hartman, 1960): A, worm in tessellated tube from off northern California; B, anterior end of same (LACM-AHF Poly8936).—C, *Kirkegaardia giribeti* (Dean & Blake, 2009): Anterior end, right lateral view (JAB).—D, *Kirkegaardia antonbruunae* n. sp., anterior end lateral view of specimen from off Peru showing tessellated tube material (USNM 1407134); E, anterior end of same, dorsal view.

Material examined. Pacific Ocean, off Ecuador, Gulf of Guayaquil, R/V *Anton Bruun*, Cruise 18B, Sta. 771-D, 03°16'S, 080°47'W, ca. 90 m, 10 Sep 1966, 1 specimen (JAB).

Description. A single, incomplete specimen from off Ecuador closely resembles *Kirkegaardia giribeti* presently known only from intertidal depths on the Pacific coast of Costa Rica. Ecuadorian fragment 4 mm long, 0.6 mm wide with 33 setigerous segments.

Pre-setigerous region 2.75x as long as wide. Prostomium short, narrow, and rounded on anterior margin; nuchal organs not observed. Peristomium 2.5x as long as wide and cut with four lateral grooves producing five annulations (Fig. 26C); low mid-dorsal ridge present along peristomium from anterior to posterior margin. Dorsal tentacles arise from posterior margin of peristomium with first pair of branchiae also on posterior margin of peristomium lateral to tentacles. Second and subsequent pairs of branchiae on posterior margin of each setiger, dorsal to notochaetae on dorsal most edge of parapodium.

Thoracic region with 25 narrow setigerous segments with parapodia shifted dorsally overlying a wide dorsal channel, each segment clearly demarcated (Fig. 26C). Transition to abdominal segments abrupt, parapodia shifting laterally, dorsal channel disappearing, and dorsum merging with lateral sides of each segment. First seven abdominal segments narrow, the last becoming longer and more moniliform.

Parapodia low ridges or mounds from which setae emerge. Thoracic notosetae numbering 6–8 long, smooth capillaries becoming wider and shorter in abdominal segments and developing fine serrations along margin; neurosetae with 5–7 smooth setae in thoracic region transitioning to shorter setae with a broad base in abdominal segments also with fine serrations along margin.

Nature of middle and posterior segments not known.

Methyl Green stain. The body stains uniformly light green, with no areas of stain concentration or any pattern evident after differentiation.

Remarks. This specimen agrees with *K. giribeti* from Costa Rica in most respects including the shape of the prostomium, long narrow peristomium, location of the dorsal tentacles and first pair of branchiae, nature of the thoracic parapodia, and the lack of any MG staining pattern. Differences include five peristomial annulations and a longer thoracic region with 25 setigerous segments in the Ecuadorian specimen instead of six peristomial annulations and 16 thoracic setigerous segments as in the Costa Rican material. However, the Ecuadorian fragment appears to be a larger specimen than the type materials and as such a longer thoracic region is to be expected. The last available abdominal segment on the Ecuadorian specimen is clearly rounded and becoming moniliform which agrees with the original description of moniliform abdominal segments.

Distribution. Costa Rica, intertidal; Off Ecuador, shallow subtidal.

***Kirkegaardia antonbruunae* new species**

Figures 26D–E; 27

Material examined. Pacific Ocean, Western South America, off Chile, SW of Valparaíso, R/V *Anton Bruun*, Cruise 18A, Sta. 687, 34.12°S, 72.32°W, 730–750 m, coll. 05 August, 1966, Menzies trawl, **holotype** and 1 **paratype** (USNM 1407132–3).—Off Peru, South of Lima, R/V *Anton Bruun*, Cruise 17, Sta. 660-C, 12°58'S, 077°16'W, 1000 m, coll. 26 Jun 1966, rock dredge, 1 specimen (USNM 1407134).

Description. An elongate species, body relatively consistent in width throughout; all segments wider than long, no elongate or moniliform segments on any specimen. Holotype and paratype incomplete; holotype 11 mm long, 0.65 mm wide across thorax for 77 setigerous segments; paratype 4.4 mm long, 0.35 mm wide, for 31 setigerous segments. Specimen from Peru mostly complete, 14 mm long, 0.7 mm wide across thorax for ca. 70 setigers. Color in alcohol light tan. Specimen from off Peru with attached tessellated tube material (Fig. 26D).

Prostomium narrow, triangular, tapering to bluntly pointed anterior margin (Figs. 26E, 27A–B; nuchal organs as curved slits at posterior margin (Fig. 27B); eyes absent. Peristomium about as wide as long; ventrally and laterally forming lips around mouth, 3–5 annular rings complete laterally and ventrally, but not cutting across smooth dorsum (Figs. 26E, 27A–B). Peristomium ending abruptly at anterior margin of setiger 1 (Fig. 27A). Dorsal tentacles positioned in notch between peristomium and anterior medial border of setiger 1 (Fig. 27A); low dorsal ridge extends from end of peristomium posteriorly over dorsum of thorax for 5–6 segments before becoming indistinguishable from dorsal surface (Fig. 27A). Branchiae first present from setiger 1, arising from posterior-

medial border, similar on following segments (Fig. 27A); branchiae on all thoracic segments, continuing to at least setiger 30 of abdominal region.

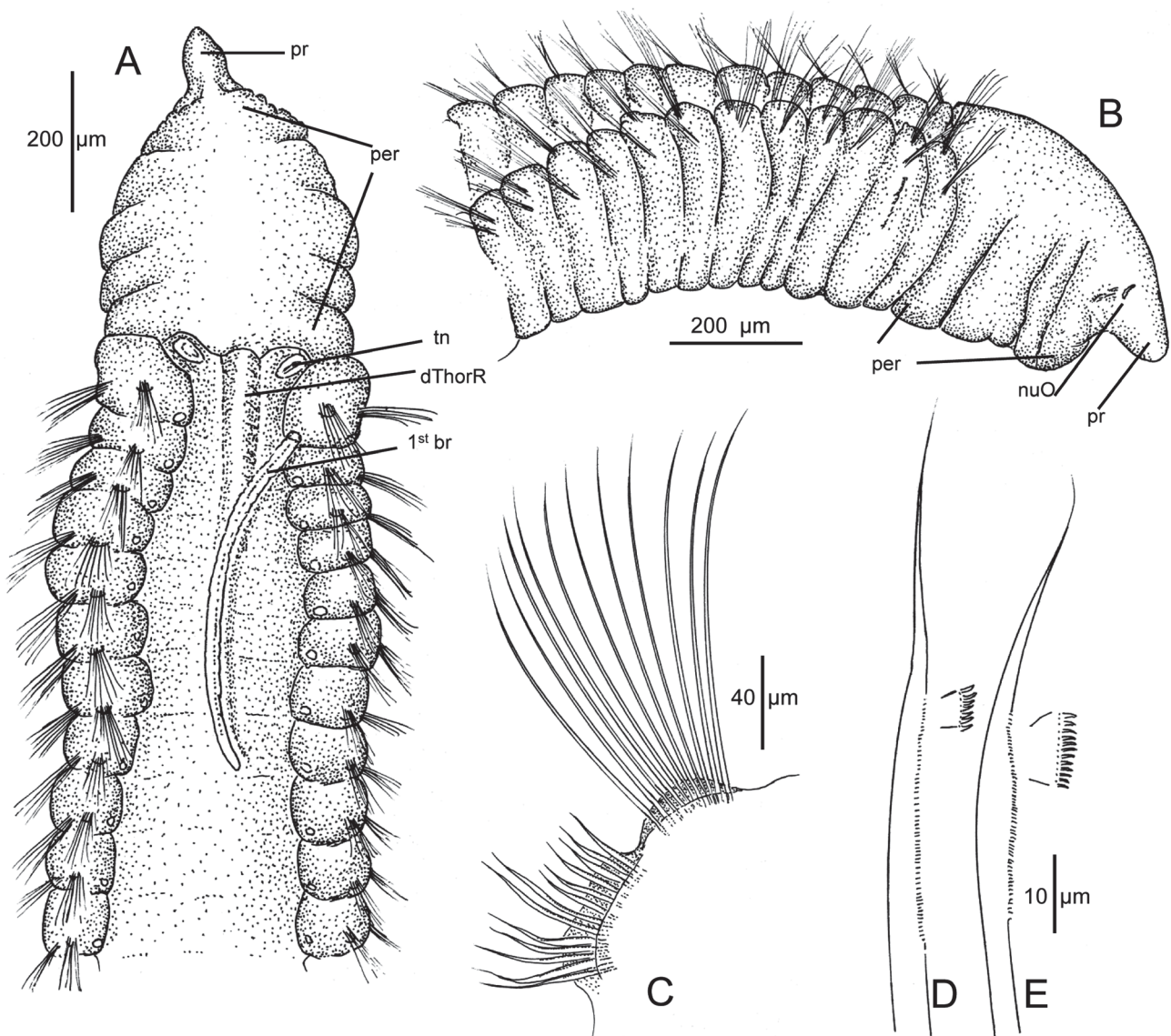


FIGURE 27. *Kirkegaardia antonbruunae* n. sp., holotype (USNM 1407132): A, anterior end, dorsal view; B, anterior end, right lateral view; C, abdominal parapodium, anterior view; D–E, abdominal neurosetae, insets not to scale.

Thoracic region of holotype with 20 setigers, characterized by parapodia elevated over broadly rounded dorsal surface (Figs. 26E, 27A); paratype with 15–16 setigers in thoracic region similar in appearance to holotype. Transition from thoracic to abdominal segments somewhat gradual with parapodia shifting to lateral position; thoracic and abdominal segments with weakly developed mid-ventral ridge consisting of a long row of elevated mid-ventral mounds at junction of each segment on venter; these poorly developed on thoracic segments, best developed on abdominal segments; each mound limited to individual segments, not crossing segmental grooves to adjacent segment. Far posterior segments dorsoventrally flattened, not expanded, best observed on specimen from off Peru.

Parapodia low narrow mounds in thoracic segments, becoming wider and more closely spaced in abdominal segments (Fig. 27C). Notosetae long, narrow, smooth capillaries throughout, numbering 20 or more per fascicle in thoracic segments and 12–15 in abdominal segments (Fig. 27C); abdominal notosetae of specimen from off Peru natatory-like in length (Fig. 26D). Neurosetae of thoracic segments and anterior abdominal segments similar to notosetae, both long and silky in appearance; from about setiger 35, neurosetae becoming shorter, thicker (Fig. 27C), with fine denticles along margin visible at 400x, but details of denticles best observed at 1000x (Fig. 27D–

E); denticulate neurosetae numbering up to 18 in a fascicle with setae appearing to be in two rows; denticles directed dorsally toward notosetae.

Pygidium unknown.

Methyl Green stain. No distinct staining reaction, entire body except tip of prostomium staining uniformly light green; body destaining rapidly upon return to alcohol.

Etymology. This species is named for the former research vessel, R/V *Anton Bruun* upon which the Southeastern Pacific Biological and Oceanographic Program (SEPBOP) program was performed; that program represented the first extensive collection of benthic invertebrates from shelf, slope, abyssal, and trench depths off western South America.

Remarks. *Kirkegaardia antonbruunae* **n. sp.** belongs to a group of species related to *K. tessellata*, *K. baptisteae*, and *K. dutchae* **n. sp.** in having similar morphology and tubes consisting of thin membranous tessellated mucoid materials. Of these, only *K. baptisteae* has denticulate notosetae and only *K. dutchae* has a mid-dorsal peristomial ridge. *K. antonbruunae* **n. sp.** and *K. tessellata*, therefore, are most closely related morphologically to one another; both species have a mid-dorsal thoracic ridge, short in *K. antonbruunae* **n. sp.** and that are lacking in the other two species. *K. antonbruunae* **n. sp.** differs from *K. tessellata* in having 3–5 prominent peristomial annular rings and abdominal segments with a mid-ventral ridge; both are lacking on *K. tessellata*. *K. antonbruunae* **n. sp.** has no MG staining pattern at all; *K. tessellata* may have a weak stain on the venter of the thorax. *K. baptisteae* also lacks a distinct MG staining reaction.

Biology. *Kirkegaardia antonbruunae* **n. sp.** has tessellated tube material (Fig. 26D) similar to that described for *K. baptisteae*, *K. dutchae*, and *K. tessellata*. No data on the habitat or sedimentology is available. The type vial contained three additional cirratulid species: *Aphelocheata* sp. (1 specimen), *Cirriformia* sp. (5 specimens), and *Dodecaceria* sp. (15 specimens). The specimen from off Peru was collected with several specimens of a large undescribed species of *Aphelocheata*.

Distribution. Continental slope off Peru, 1000 m; off Chile, SW of Valparaiso, 737–750 m.

***Kirkegaardia araiotrachela* new species**

Figure 28

Material examined. Pacific Ocean, Western South America, off Peru, west of Trujillo, La Libertad Province, R/V *Anton Bruun* Sta. 85, 14 Oct 1965, 07°53'S; 80°30'W, 520 m, Menzies trawl, **holotype** (USNM 1013893); South of Lima, R/V *Anton Bruun*, Cruise 17, Sta. 660-A, 12°27'S, 077°16'W, 805 m, coll. 25 Jun 1966, Campbell grab, 1 specimen (USNM 1407135).

Description. Holotype posteriorly incomplete, with about 75 setigers, 22 mm long; width variable depending upon body region: 0.4 mm wide across peristomium and some anterior setigers, 1.0 mm wide at enlarged area between setigers 18–30, and 0.6–0.7 mm wide in middle posterior segments, (Fig. 28A). Specimen from off Lima, Peru smaller, 9 mm long, 0.5 mm wide across thorax, 1.4 mm wide across expanded mid-body region, for 43 setigerous segments. Color in alcohol: light tan.

Body narrow over first 15–16 setigers comprising a thoracic region with narrow segments about 3.5x wider than long, then followed by expanded anterior abdominal section with segments 5.5x as wide as long over next 10 setigers (Fig. 28A), then narrowing again in middle and posterior abdominal segments; these becoming longer, about 1.5x as long as wide. Venter with prominent groove from end of thoracic region to end of fragment.

Prostomium narrow, triangular, tapering to pointed anterior tip; eyes absent, nuchal organs not observed. Peristomium with one large and two narrow annular rings with groove visible only laterally, not cutting across smooth dorsum; first ring a large inflated annulus followed by two narrower annulae (Fig. 28A) appearing to be two achaetous segments; dorsum of peristomium smooth, rounded. Dorsal tentacles short, possibly regenerating, arising from second annular ring and well anterior to setiger 1 (Fig. 28A). First pair of branchiae from posterior border of third annular ring and anterior to setiger 1; second pair of branchiae on posterior border of setiger 1, dorsal to notosetae; subsequent branchiae arising in a similar location; branchiae rarely observed in posterior segments.

Parapodia reduced to low ridges; lacking postsetal lamellae; notosetae thick, with thick brown bases and include smooth to finely denticulated capillaries, with short, pointed denticles most visible in setae of middle body segments (Fig. 28B). Anterior neurosetae including fascicles of thin, broad-bladed capillaries, with sharply tapering tips; in middle body setigers, these setae with fine denticles or serrations at point of abrupt tapering (Fig.

28C–D); these broad-bladed pointed setae transitioning to sharply pointed spines and then blunt-tipped spines (Fig. 28E) in posterior segments from about setiger 68, both types of setae in same fascicle, alternating with narrow, smooth capillaries (Fig. 28F). Non-type specimen with many setae sheared off along body precluding confirmation of all setal observations made on holotype; however, neurosetae with serrations at point of abrupt tapering present on next to last segment of smaller specimen; spines not present on this fragment.

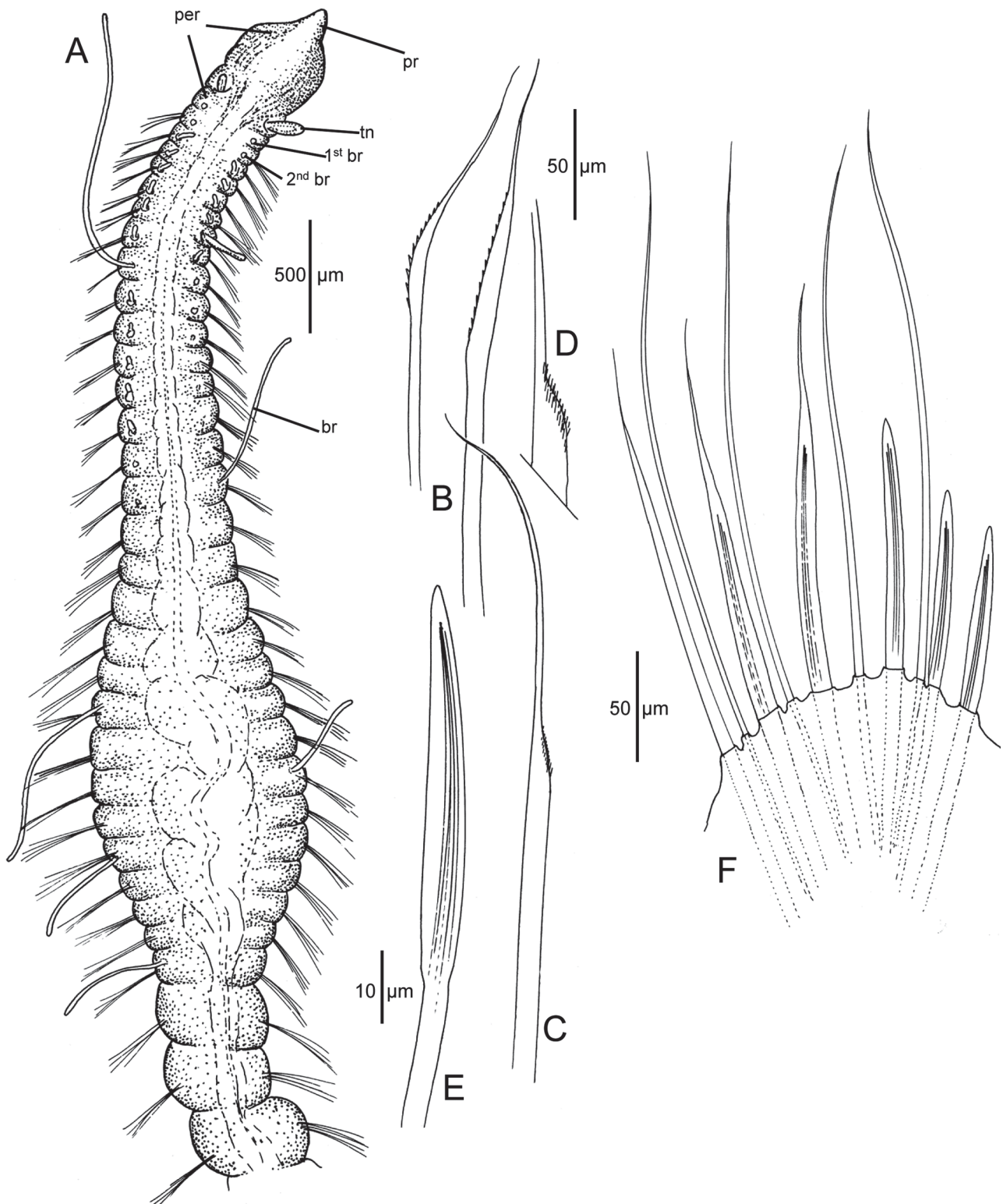


FIGURE 28. *Kirkegaardia araiotrachela* n. sp., holotype (USNM 1013893): A, Anterior and middle body segments, dorsal view; B, denticulated notosetae; C, serrated neuroseta from middle body segments; D, same, detail of serrated area, not to scale; E, posterior neuropodial blunt-tipped spine; F, posterior neuropodium, with pointed, tapering spines, blunt-tipped spines, and simple capillaries.

Pygidium not observed.

Etymology. *Araiotrachel* is from the Greek: *araios* for narrow, thin; *trachelos* for neck. The name is suggested by the narrow neck-like region of the anterior end that precedes the enlarged, fusiform expanded section.

Methyl Green stain. Prostomium retaining light green stain; peristomium and rest of body not retaining stain after differentiation.

Remarks. There are many unusual features of *Kirkegaardia araiotrachela* **n. sp.** suggesting that a further evaluation of its generic status is warranted. The occurrence of the paired dorsal tentacles on the middle annular ring of the peristomium is unusual in being so far anterior on the peristomium. The occurrence of branchiae on the last annular ring suggests this might be an achaetous segment rather than part of the peristomium. The denticulate capillaries found in middle body notopodia are typical of those found in several species of *Kirkegaardia*, but these are normally in the neuropodia as well, rather than limited to the notopodia. The heavy, thickened, pointed neurosetae with denticles or serrations evident at the point of narrowing begin from setigers 5–6 and transition to spines having either long, tapering tips or shorter blunt tips; in posterior setigers both types of spines intergrade within a single neuropodium and alternate with long, slender capillaries; damage to the notosetae in the second specimen precludes confirmation of these observations on another specimen. For this reason it is difficult to confirm the distribution of the different forms of spines observed on the holotype except that the blunt-tipped spines are first observed from setiger 68, with their homologues beginning in anterior setigers. This type of setal transition appears to be unique among the bitentaculate cirratulids studied to date. The alternation of thin capillaries and spines in the neuropodia, as occurs in *K. araiotrachela* **n. sp.**, also occurs in related bi-tentaculate species of *Chaetozone*. However, *Chaetozone* species also have these spines and capillaries in the notopodia which together with the neuropodial spines form posterior cinctures with a distinct armature (Blake 2015). Heavy spines are absent in notopodia of *K. araiotrachela* **n. sp.** and true cinctures are not developed. There are no known species of *Chaetozone* that have denticulate or serrated setae. Setae with serrations evident only at the point of narrowing were illustrated by Eliason (1962) for a cirratulid from the Skagerrak off Sweden that he named *Caulleriella serrata*. It is likely that upon re-examination Eliason's species will be referred to *Kirkegaardia*. However, *C. serrata* does not have the more typical denticulated setae as in *K. araiotrachela* **n. sp.** or other species of the genus.

Biology. The inflated portion of the body of *K. araiotrachela* **n. sp.** is possibly related to sexual maturity because sperm packets are present in the coelom of the holotype. No other information is available relative to the habitat or associated organisms.

Distribution. Known only from off Peru in 520–805 m.

***Kirkegaardia chilensis* new species**

Figure 29

Tharyx spp. Hartman 1967:118 (in part).

Material examined. Pacific Ocean, off Western South America, Southwestern Chile, off Valparaiso, USNS *Eltanin* Cruise 9, Sta. 750, 33.02°S, 71.88°W, 624 m, coll. 26 September 1963, Petersen grab, **holotype** and **paratype** (USNM 1013897–8); Cruise 5, Sta. 208, off Concepcion, 35.65°S, 73.13°W 957 m, coll. 11 September 1962, Menzies Trawl, 7 **paratypes** (USNM 56079), 1 additional **paratype** (USNM 1013899).

Description. A small species with thin, narrow body; holotype incomplete, 11.7 mm long, 0.35 mm wide across thorax for 56 setigers. Color in alcohol: light tan, no pigment apparent.

Each specimen with very elongate, smooth peristomial region; thoracic region narrow, with 16–20 crowded segments; venter swollen between about setigers 8–14 (Fig. 29A); long abdominal region with longer segments, sometimes weakly moniliform; posterior end remaining narrow, not expanded in mostly complete paratypes, pygidium missing from all specimens. Abdominal segments with venter flattened, with weak mid-ventral channel containing low ridge extending along midline. Parapodia of thoracic region elevated over dorsal surface producing distinct mid-dorsal channel; middle surface of this channel raised forming a weak and narrow ridge (Fig. 29B).

Pre-setigerous region elongate, 1.9x as long as wide. Prostomium short, oval, broadly rounded on anterior margin (Fig. 29A–B); eyes absent; nuchal organs not observed. Peristomium about 1.8x as long as wide, smooth, with two weakly developed lateral grooves, often not apparent (Fig. 29A–B); mid-dorsal peristomial ridge or crest

absent; short proboscis everted on some specimens. Dorsal tentacles arising from posterior part of peristomium (Fig. 29A–B); first pair of branchiae also on peristomium, posterolateral to dorsal tentacles (Fig. 29A–B); second pair of branchiae on setiger 1 (Fig. 29B); following branchiae at posterior margin of individual setigers, dorsal to notosetae; branchiae all short, most missing.

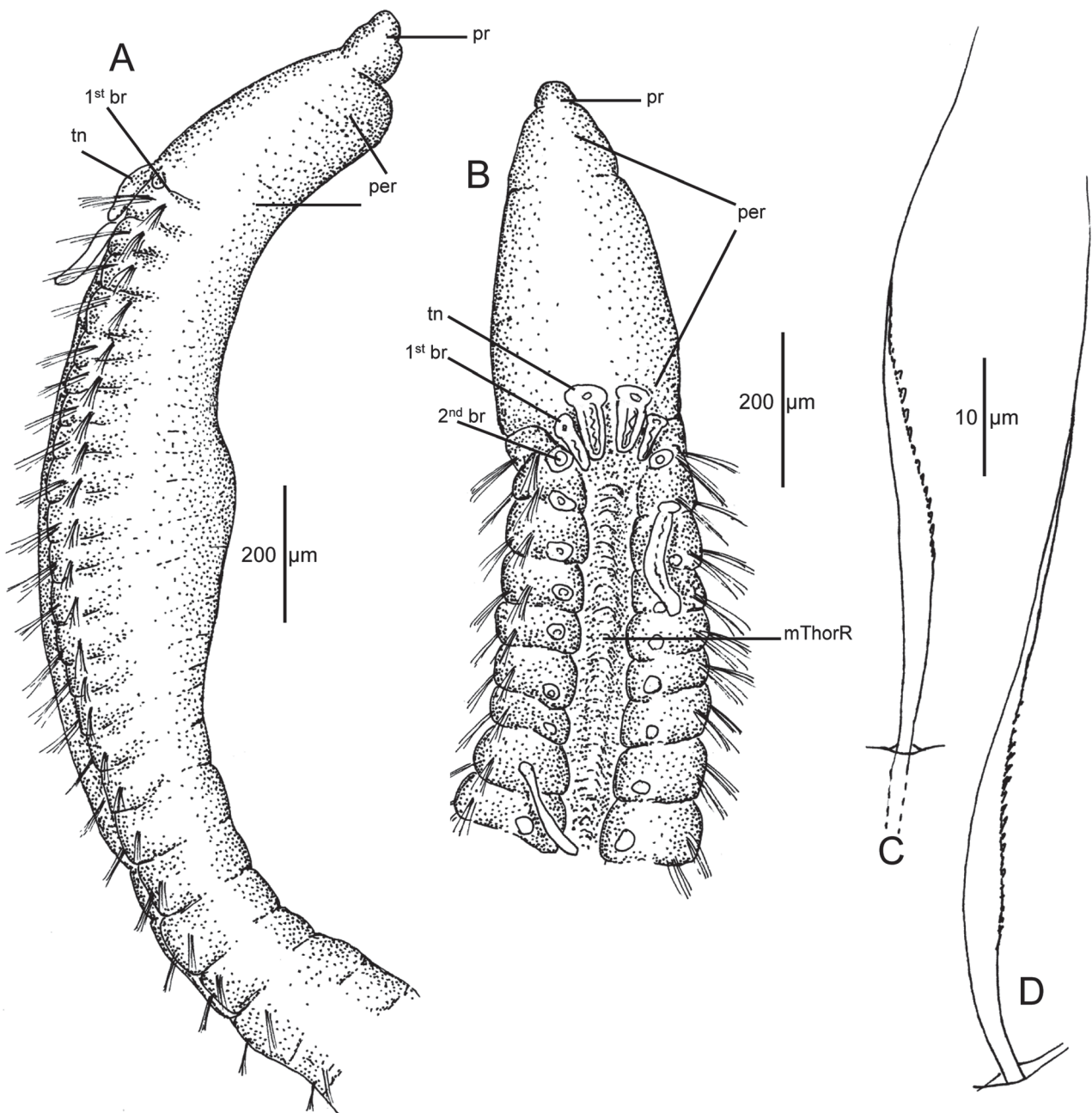


FIGURE 29. *Kirkegaardia chilensis* n. sp., holotype (USNM 1013897): A, anterior end, right lateral view; B, anterior end, dorsal view; C–D, abdominal denticulated neurosetae.

Parapodia well developed in thoracic region, dorsally forming lateral borders of dorsal groove (Fig. 29B); parapodia reduced to setal tori posteriorly. Notosetae long capillaries throughout, up to 7–9 per fascicle in anterior setigers, decreasing to 5–6 posteriorly; denticulated notosetae absent; neurosetae, shorter, thicker than notosetae, numbering 8–10 per fascicle, with very fine denticles along shaft in middle abdominal setigers from setiger 30, visible only at 1000x (Fig. 29C–D).

Methyl Green stain. Venter of expanded part of thorax stains weakly, otherwise no staining reaction.

Etymology. This species is named for its location on the Chilean continental slope.

Remarks. *Kirkegaardia chilensis* n. sp. is part of the group of 12 species having the thoracic parapodia

elevated over a mid-thoracic channel and is most similar morphologically to *K. dorsobranchialis*, *K. carinata* n. sp., and *K. cryptica* in having an entirely smooth peristomium with no dorsal ridge. Of these, *K. carinata* n. sp. and *K. chilensis* n. sp. have a prominent mid-dorsal ridge within the thoracic dorsal channel that is absent in both *K. dorsobranchialis* and *K. cryptica*. *K. chilensis* n. sp. differs from *K. carinata* n. sp. in having only a weak MG staining pattern limited to the thoracic region instead of the intense and spectacular pattern on the peristomium, thoracic region, and abdominal parapodia of *K. carinata* n. sp. In addition, the mid-ventral segments of the thoracic region of *K. chilensis* n. sp. are expanded, whereas all of the thoracic segments of *K. carinata* n. sp. are the same size.

Distribution. Off western Chile, slope depths of 624–957 m.

***Kirkegaardia jumarsi* new species**

Figure 30

Material examined. Pacific Ocean, off Western South America, Peru-Chile Trench, R/V *Anton Bruun*, Cruise 17, Sta. 664-C, 13°41'S, 077°50'W, Menzies trawl, 5430 m, coll. 29 Jun 1966, **holotype** (USNM 1407135).

Description. Holotype incomplete, well-preserved but fragile, 21 setigerous segments breaking into two parts during handling, collectively 7.6 mm long, 0.8 mm wide across expanded thoracic region.

Head or pre-setigerous region as wide as long and with thoracic segments forming thick, bulbous, expanded anterior region. Prostomium broadly triangular, with anterior end apically rounded and turned up dorsally (Fig. 30A–B); nuchal organs narrow slits; eyes absent. Mouth large, with emerging bulbous proboscis, surrounded by thick lateral peristomial lips (Fig. 30B); peristomium divided into two more or less equal annular rings; anterior ring with smooth, dorsal dome and thick lateral lips surrounding mouth; second ring with relatively smooth dorsum, laterally subdivided into 2–4 narrow lateral rings (Fig. 30A–B).

Thorax expanded, with only seven setigerous segments, narrowing to four moniliform abdominal segments that twist sharply at setiger 12, with posterior abdominal segments 12–21 forming a right angle to anterior segments 1–11. Figures (30B–D) show a numerical sequence and shape of first 19 setigers.

Dorsal tentacles arising from peristomium mid-dorsally near border with setiger 1 (Fig. 30A). First pair of branchiae short, located on posterior margin of peristomium in groove anterior to setiger 1 and lateral and dorsal to tentacles (Fig. 30A); second pair of branchiae and following thoracic branchiae located on posterior edge of each parapodium overlying mid-dorsal groove (Fig. 30A); most branchiae missing, but scars evident. Branchiae of abdominal segments not readily evident, but a few segments with short branchiae intact arising near notosetae (Fig. 30D).

Thoracic segments short, about 6x as wide as long, anterior and posterior margins of each thoracic segment with thickened borders, parapodia dorsally elevated forming shallow dorsal groove (Fig. 30A). Segmental boundaries of thoracic segments visible on dorsal surface with distinct lines demarking each segment (Fig. 30A). Setigers 1–7 all similar, but with setigers 1–3 swollen ventrally (Fig. 30B); thoracic setiger 7 followed abruptly by four moniliform abdominal setigers 8–11 (Fig. 30B–C); abdominal setigers 9–11 about as long as wide, distinctly moniliform (Fig. 30C); setigers 12–13 elongate and narrow about 2x as long as wide (Fig. 30D); setigers 14–17 then becoming shorter, about 2.5x as wide as long (Fig. 30D); setiger 18 and rest of holotype with long, narrow segments.

Parapodia of thoracic region well developed, with distinct tori from which setae arise. Notosetae elongate, smooth capillaries throughout, numbering 12–15 per notopodium in thoracic region, continuing in abdominal segments, reduced to 8–10 in posteriormost notopodia. Neurosetae similar in number, elongate smooth capillaries to setiger 13, then abruptly transition to 14–16 short, broad-based denticulated setae arranged in two rows. Denticles visible at 400x, but details apparent only at 1000x where numerous pointed denticles along one narrow margin observed (Fig. 30E), with crease of each set of denticles extending entirely across spine, almost forming spiral pattern.

Far posterior segments and pygidium unknown.

Methyl Green stain. No stain retained on holotype.

Etymology. This species is named for Dr. Peter Jumars, deep-sea biologist and benthic ecologist, who described the first species of the unusual mud-ball worms from off southern California.

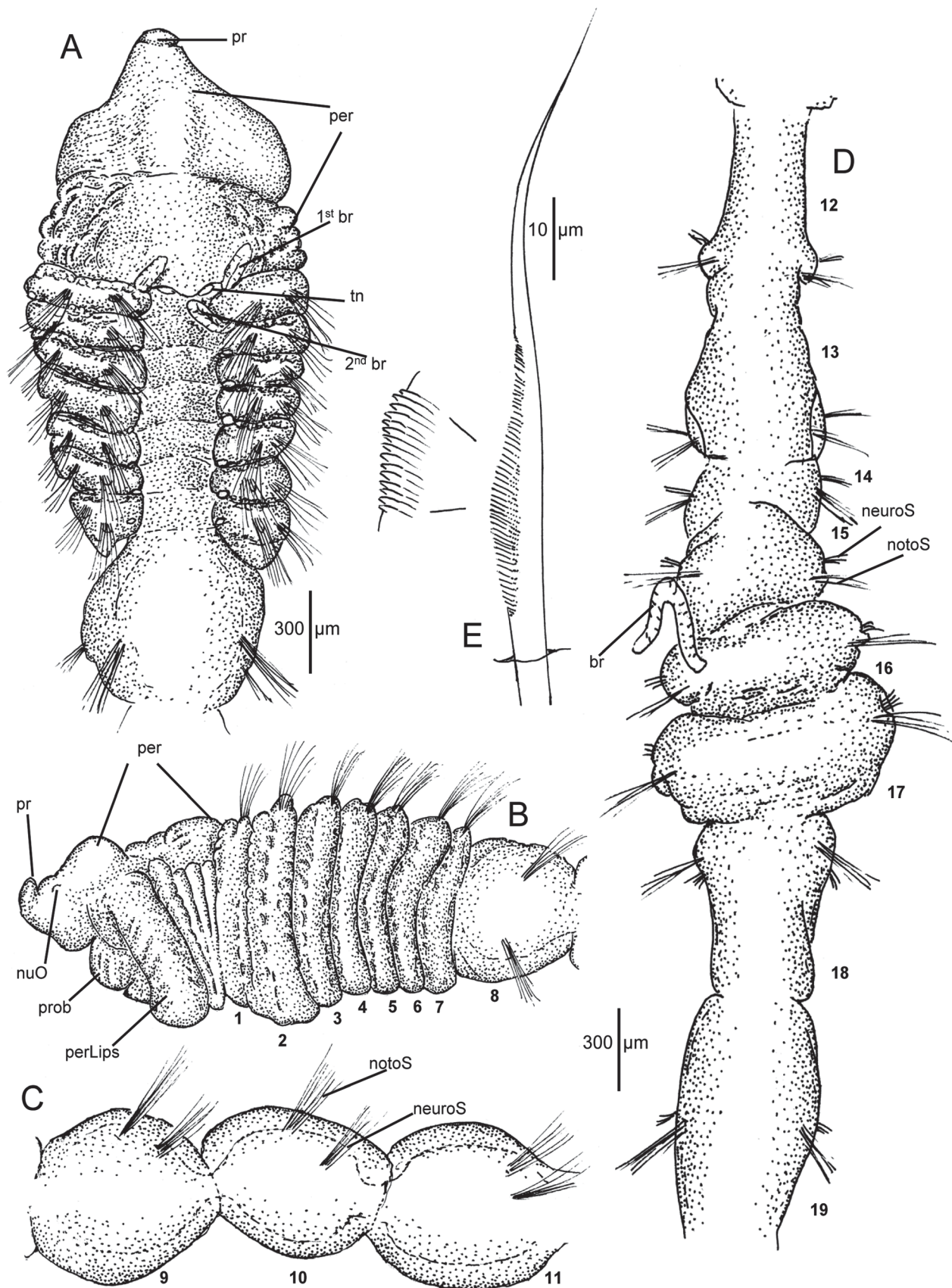


FIGURE 30. *Kirkegaardia jumarsi* n. sp., holotype (USNM 1407135): A, anterior end, dorsal view; B, same, left lateral view; C, abdominal setigers 9–11 in left lateral view; D, abdominal setigers 12–19 in dorsal view; E, abdominal denticulated neuroseta, inset not to scale.

Remarks. With the description of *K. jumarsi* n. sp. and *K. olgahartmanae* n. sp. (see below), there are now three species of unique deep-water mud ball worms, *K. luticastella* being the first described. All three species have an expanded, modified thoracic region followed by a narrow, twisted abdominal region that conforms to the shape of its tube within a hardened mud ball.

Kirkegaardia jumarsi n. sp. appears to be most similar to *K. luticastella* in having short thoracic parapodia that are elevated sufficiently high to overlie a relatively smooth dorsal surface. In *K. luticastella* n. sp., this dorsal thoracic surface is smooth, whereas that of *K. jumarsi* n. sp. is cut with thin lines demarking each segment. The pre-setigerous region of both species is short, enlarged, and about as long as wide, which together with the expanded thoracic region provides both species with an enlarged and thickened anterior end to the body. Although of similar size and shape, details of the pre-setigerous area of the two species differ considerably. In *K. luticastella* the entire peristomium is relatively smooth and only incised by a single groove to varying degrees. In larger specimens the groove is barely evident, in smaller specimens such as the one from off northern California (Fig. 17A), the lateral groove is prominent. In *K. jumarsi* n. sp., on the other hand, the main lateral groove divides the peristomium such that the anterior half laterally and ventrally forms large lateral lips around the mouth and is overlaid with a rounded dorsal crest or dome. The second half of the peristomium, while smooth dorsally, is divided laterally into at least four narrow ridges (Fig. 30A–B). Comparison of these two species with the third mud ball species, *K. olgahartmanae* n. sp., is discussed below.

Biology. The shape of the body with an expanded, almost bulbous, anterior end followed by a narrow twisted abdominal region is similar to that of two other species of mud ball worms. It is here postulated that *K. jumarsi* n. sp. produces and inhabits mud balls similar to those described for *K. luticastella* by Jumars (1975) and *K. olgahartmanae* (see below). Although all mud ball worms to date are from deep-water, *K. jumarsi* n. sp. is the first to be reported from abyssal depths greater than 5000 m.

Distribution. Known only from the Peru-Chile Trench off Peru in 5430 m.

Species of *Kirkegaardia* from the Southern Ocean and Antarctica

Kirkegaardia herosae new species

Figure 31

Material examined. Argentina, off Tiera del Fuego, Staten Island, R/V *Hero* Cruise 712, Sta. 665, 54.742°S, 63.882°W, 44 m, 11 May 1971, Petersen grab, **holotype** and **paratype** (USNM 1013894–5); Sta. 659, 54.858°S, 64.452°W, ca. 33 m, 01 May 1971, Petersen grab, **2 paratypes** (USNM 1013896).

Description. A moderately sized species, holotype with 39 segments, 4.6 mm long, 1 mm wide across expanded thorax; smaller paratype with 40 setigers, 4 mm long, 0.35 mm wide across thorax. Color in alcohol: light tan, no pigment apparent.

Pre-setigerous region relatively short, 1.3x as long as wide. Prostomium short, triangular, narrowly rounded on anterior margin (Fig. 31A–B); nuchal organs not apparent; eyes absent. Peristomium wider than long, with three annulations formed by four grooves; first annulation following prostomium enlarged, expanded laterally; then followed by two narrow rings resembling achaetous segments (Fig. 31B); dorsum of these last two rings with elevated crest terminating anteriorly with large peristomial ring and posteriorly at setiger 1, more or less merging with dorsal surface of thoracic segments (Fig. 31A–B). Dorsal tentacles arising on third peristomial ring immediately anterior to setiger 1; first pair of branchiae arising posterior to dorsal tentacles in middle of setiger 1; second pair of branchiae also on setiger 1, arising dorsal to notosetae on posterior margin of segment (Fig. 31B); subsequent segments with branchiae on posterior margin of segment; branchiae thin, wrinkled, most missing.

Thoracic region with about 28 narrow, crowded segments; broadly swollen from about segments 12–27 (Fig. 31A); abdominal segments moniliform; posterior end narrow, expanding in far posterior segments. Dorsum of thoracic region smooth, rounded, without dorsal groove or ridge; venter with deep mid-ventral groove.

Parapodia well developed in thoracic region, forming distinct shoulders, but not elevated over dorsal surface; dorsally parapodia merging indistinctly with dorsal surface; parapodia with reduced setal tori posteriorly. Noto- and neurosetae of anterior setigers long simple capillaries, golden colored, dark at bases, numbering 7–8 per fascicle, decreasing to 4–5 posteriorly; neurosetae broader, thicker than notosetae in first 10–15 setigers; from

about setiger 30, noto- and neurosetae with serrated edge formed by separated fibrils (Fig. 31C–D), serrations visible at 400x.

Methyl Green stain. Entire body staining uniformly; middle of thorax with 3–4 segments with deeper turquoise band completely encircling body. Intersegmental areas staining darker turquoise.

Etymology. This species is named for the R/V *Hero*, former research vessel of the U.S. Antarctic Program.

Remarks. *Kirkegaardia heroae* n. sp. is provisionally assigned to *Kirkegaardia* n. nom. The noto- and neurosetae are thick and have prominent serrations along one edge, but these are not the denticulate type of seta that characterizes other species of the genus. Among the Antarctic cirratulids examined as part of this study, *K. heroae* n. sp. is the only species to have such a long thorax with an expanded region. In *K. chilensis* n. sp., the thorax is also expanded, but only ventrally. The moniliform abdominal segments are more characteristic of some species of *Aphelochaeta*, such as the type species, *A. monilaris* (Hartman) and it is possible that *K. heroae* n. sp. may be reassigned pending further study.

Superficially, *K. heroae* n. sp. resembles *K. araiotrachela* n. sp. in overall body shape and in having one large and two small peristomial annular rings. However, the two species have different parapodial morphologies and different kinds of setae.

Distribution. Antarctic Peninsula, in shelf depths.

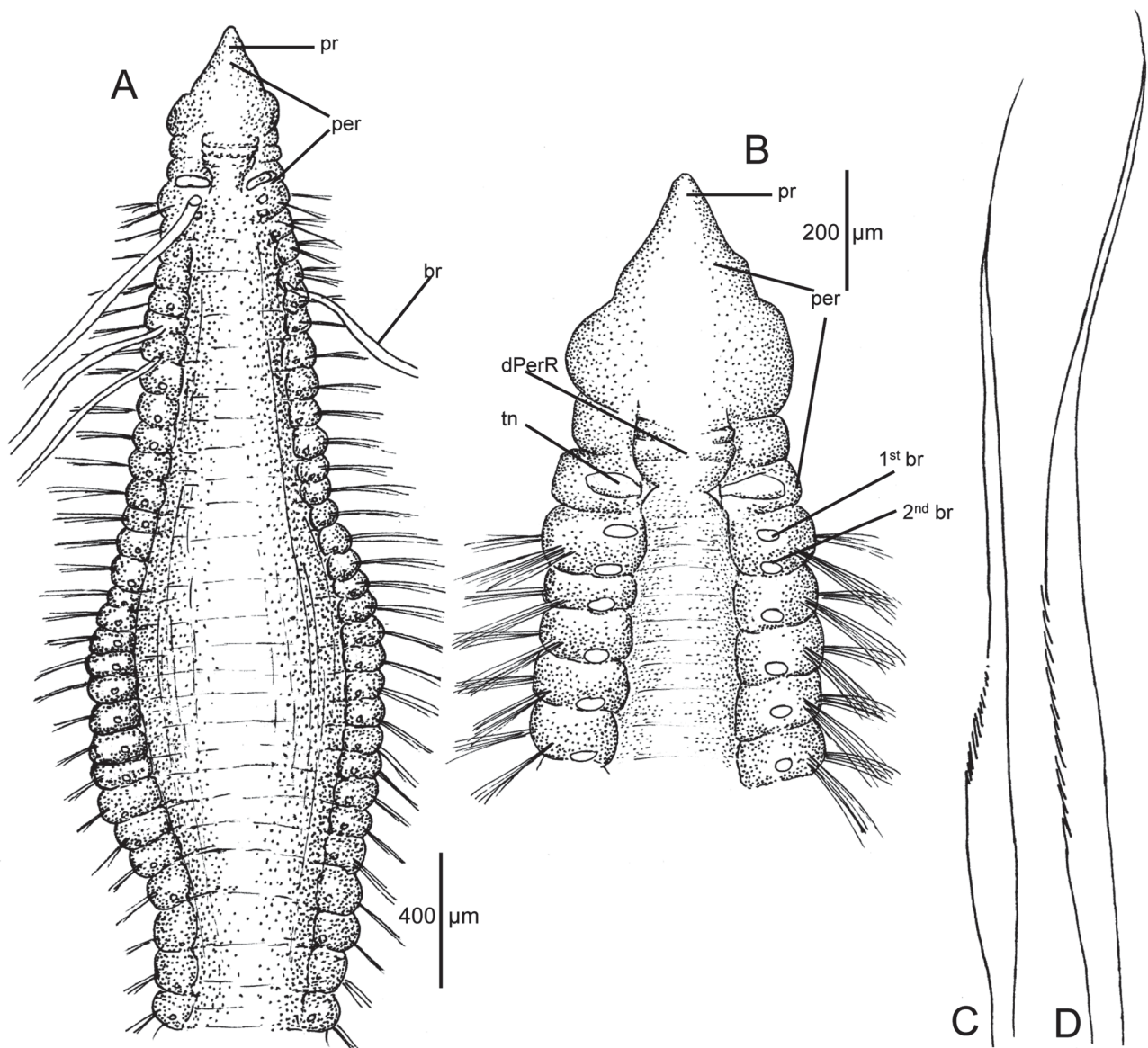


FIGURE 31. *Kirkegaardia heroae* n. sp., holotype (USNM 1013894): A, anterior end, dorsal view; B, same, with more detail; C–D, abdominal neurosetae.

***Kirkegaardia brigitteae* new species**

Figures 32–33

Monticellina sp. 2: Hilbig 2001: 540; Hilbig *et al.* 2006: 714–719; Montiel *et al.* 2015: Appendix 1.

Material examined. **Weddell Sea, Halley Bay**, R/V *Polarstern*, EASIZ II Cruise (ANT-XV/3), Sta. 48-136, 74°33.0'S, 27°13.1'W, 2012 m, 09 Feb 1998, multibox corer, coll. B. Ebbe, **holotype** (ZMH P-27812).—**Weddell Sea, Drescher inlet, South of Vestkapp (West Cape)**, R/V *Polarstern*, EASIZ II Cruise (ANT-XV/3), Sta. 48-091, 73°28.4'S, 22°48.8'W, 1510 m, 04 Feb 1998, multibox corer, coll. B. Ebbe, 7 **paratypes** (ZMH P-27807); Sta. 48-093, 73°28.3'S, 22°54.5'W, 1988 m, 04 Feb 1998, multibox corer, coll. B. Ebbe, 15+ **paratypes**, were dry and rehydrated (ZMH P-27808); Sta. 48-131, 73°23.7'S, 22°09.1'W, 1985 m, 08 Feb 1998, multibox corer, coll. B. Ebbe, 9 **paratypes** (ZMH P-27809); Sta. 48-132, 73°20.7'S, 22°18.4'W, 2387 m, 08 Feb 1998, multibox corer, coll. B. Ebbe, 7 **paratypes** (ZMH P-27810).—**Powell Basin, SW of South Orkney Islands**, R/V *Polarstern*, ANDEEP III Cruise (ANT-XXII/3), Sta. 150-3, 61°48.63'S, 47°27.67'W, 1956 m, 20 Mar 2005, 0.25m², box corer, 1 specimen (ZMH P-27813); Sta. 150-8, 61°48.56'S, 47°27.48'W, 1942 m, 20 Mar 2005, multi corer, 1 specimen (ZMH P-27814); 1 specimen SEM (JAB).—**Antarctic Peninsula, South Shetland Islands, off King George Island**, R/V *Polarstern*, EASIZ II Cruise (ANT-XV/3), Sta. 48-330, 61°20.6'S, 58°15.1'W, 2009 m, 18 Mar 1998, multibox corer, coll. B. Ebbe, 1 specimen (JAB).—**Bellingshausen Sea, NW Anvers Island**, R/V *Polarstern*, ANDEEP III Cruise (ANT-XXII/3), Sta. 154-3, 62°31.52'S, 64°39.64'W, 3801 m, 30 Mar 2005, multi corer, 1 specimen (ZMH P-27815).

Description. A moderately sized, threadlike species; none complete, but several posterior fragments appear to belong to the species. Holotype largest specimen, 16 mm long, 0.5 mm wide across thoracic segments and 0.8 mm wide across abdominal segments for 65 setigerous segments. Posterior fragments greatly expanded, up to 3 mm long, 0.8 mm wide with up to 22 segments; these suggest that complete worms would be at least 20 mm long and have 80 or more segments. Body light tan in alcohol with no obvious pigment. Pre-setigerous region elongate, narrow, approximately 2.5x as long as wide (Figs. 32A–B, 33A–B), as long as first eight setigers of thoracic region on largest specimens. Prostomium short, conical, curved ventrally, tapering to rounded anterior margin (Fig. 32A–B); eyes absent; nuchal organs narrow slits at posterolateral border. Peristomium elongate, narrow, relatively smooth throughout, lacking distinct lateral grooves (Fig. 32A–B); anterior one-third to one-half of peristomium with a distinct mid-dorsal ridge continuous with prostomium (Fig. 32A–B); dorsal surface of remaining peristomium smooth. Transition of peristomium to setigerous segments indistinct, merging smoothly with mid-dorsal channel of thoracic region (Fig. 32A). Dorsal tentacles arising close together anterior to level of setiger 1; first pair of branchiae lateral to these tentacles (Fig. 32A–B); second pair of branchiae on posterior dorsal border of setiger 1; subsequent branchiae in similar locations overlying mid-dorsal channel (Fig. 32A). Most branchiae evident as stubs; branchiae rarely observed in abdominal segments.

Thoracic segments numbering 6–12, smaller specimens with fewest; each thoracic segment short, 3.5x wider than long, parapodia shifted dorsally, overlying a mid-dorsal channel, with narrow ridge along midline of channel (Fig. 32A). Abdominal segments becoming longer, almost as wide as long (Fig. 32C), segments narrowing, becoming somewhat moniliform in posterior, last 15 or so segments greatly expanded; pygidial segment with dorsal anus overlying short conical ventral lobe (Fig. 32D); ventral surface of far posterior segments with low mid-ventral ridge; other regions of body without ventral groove or ridge.

Parapodia of thoracic segments best developed as distinct raised noto- and neuropodial lobes (Fig. 32A–B), continuing in abdominal segments (Fig. 32C). Thoracic parapodia shifted dorsally (Fig. 32B), abdominal parapodia in lateral locations (Fig. 32C). Setae of thoracic region initially all smooth capillaries transitioning to denticulated setae in last thoracic segments and anterior abdominal segments. Thoracic notosetae numbering 6–8, neurosetae 6–10 per fascicle, depending on size of worm; abdominal notosetae numbering 4–7 per fascicle, neurosetae 4–7. Notosetae longer, thinner than shorter, thicker neurosetae especially on abdominal segments. Noto- and neurosetae with denticles first present from anteriormost abdominal setigers, 12–14 in largest specimens; denticles larger and more prominent on neurosetae (Fig. 33E) than on notosetae (Fig. 33G); notosetae with denticles directed ventrally in fascicles, denticles of neurosetae directed dorsally, *vis-à-vis*. In light microscopy only the denticles along the cutting edge visible, best seen at 1000x (Fig. 32E). With SEM large blunt-tipped denticles seen to occur along the cutting edge of each neuroseta, with numerous smaller denticles or thick fibrils occurring lateral to larger denticles (Fig. 33E–F); notosetae with most denticles on cutting edge of a similar size to lateral denticles (Fig. 33G).

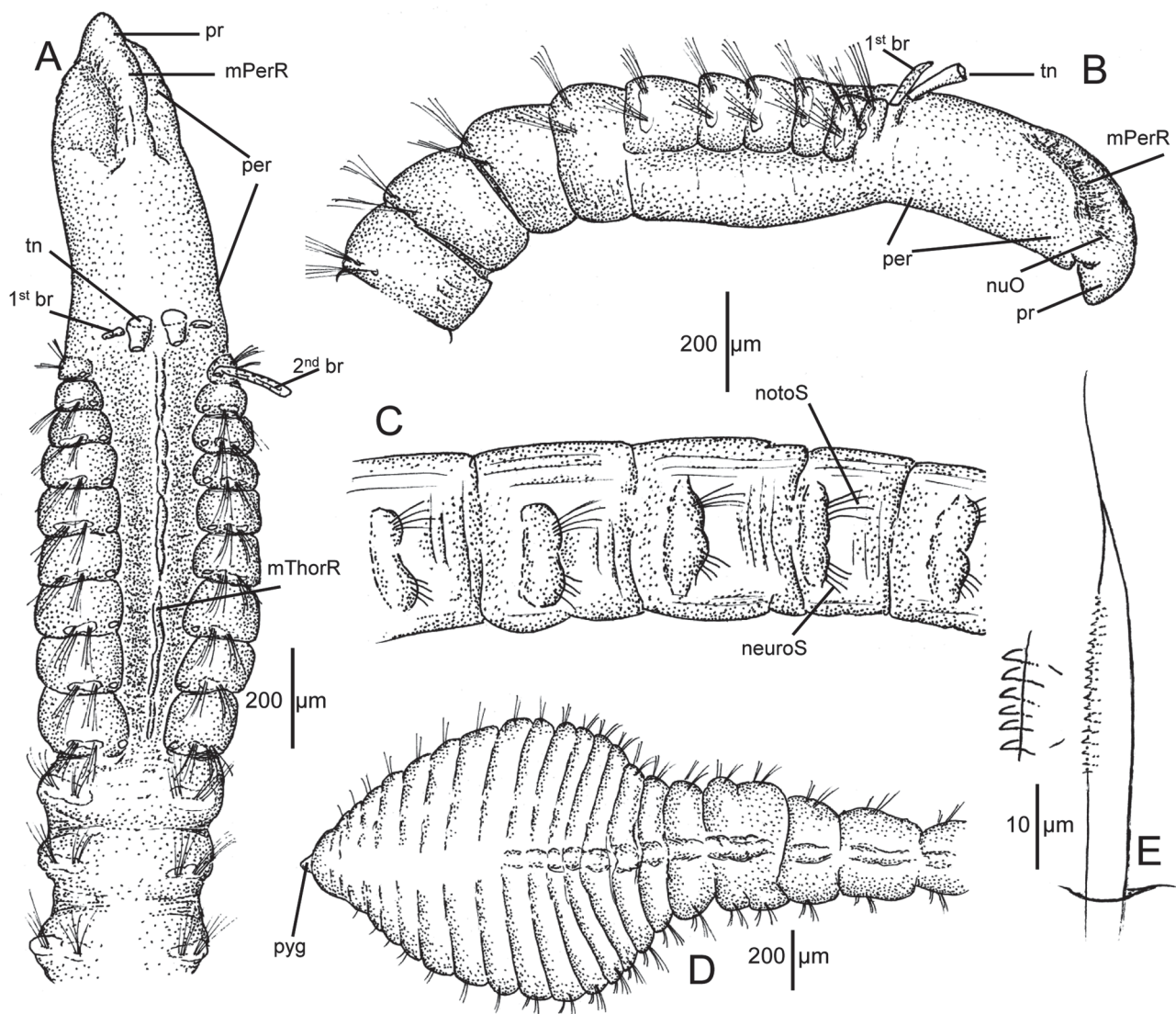


FIGURE 32. *Kirkegaardia brigittae* n. sp., paratypes, EASIZ II Sta.48-132, (ZMH P-27810): A, anterior end, dorsal view; B, anterior end in right lateral view of another paratype; C, anterior abdominal segments, left lateral view; D, posterior end, dorsal view; E, denticulate neuroseta from middle abdominal segment with inset (not to scale).

Methyl Green stain. The peristomium retains an overall diffuse green stain, with a darker posterior dorsal patch developed to variable degrees. The middle and posterior segments of the thoracic region are stained as broad blue bands that encircle each segment up to the border of the mid-dorsal channel but leaving the actual parapodia unstained (Fig. 33A–C); the stain is an intense dark blue on the last 2–3 thoracic segments (Fig. 33A). The abdominal segments retain a bright green stain laterally on each parapodium and a mid-ventral spot or short longitudinal band (Fig. 33D).

Etymology. This species is named for Dr. Brigitte Ebbe, benthic ecologist and polychaete systematist, who collected the majority of these specimens and provided them to me for study. Dr. Ebbe is a long-time colleague and authority on deep-water benthos of Antarctica and elsewhere.

Remarks. *Kirkegaardia brigittae* n. sp., a deep-sea Antarctic species, is most closely related morphologically to the type-species of the genus, *K. heterochaeta*, from shallow subtidal habitats in the Mediterranean Sea. The two species are similar in having a distinct mid-dorsal ridge that extends from the prostomium to part way along the peristomium, leaving the rest of the dorsal peristomial surface smooth; a mid-dorsal thoracic ridge; and similar MG staining patterns. The two species differ in that in *K. heterochaeta* the mid-dorsal thoracic ridge encompasses the entire dorsal surface of the channel, whereas in *K. brigittae* n. sp., there is a separate narrow ridge on the larger dorsal surface within the channel. Further, the peristomium of *K. heterochaeta* has at least one lateral groove



FIGURE 33. *Kirkegaardia brigitteae* n. sp., photomicrographs of methyl green staining pattern of paratypes, EASIZ Sta. 48-131 (ZMH P-27809): A, anterior end, dorsolateral view; B, anterior end, dorsolateral view; C, anterior end, dorsal view; D, middle abdominal segments, ventral view.—Scanning electron micrographs of denticulated setae from specimen from ANDEEP III Sta. 150-8: E, denticulated neurosetae from anterior abdominal segment; F, details of one denticulated neuroseta; G, denticulated notosetae from an anterior abdominal segment.

producing two annular rings, whereas *K. brigittae* **n. sp.** has none. The far posterior pre-pygidial segments of *K. brigittae* **n. sp.** include about 15 segments that are greatly expanded, whereas the same segments of *K. heterochaeta*, although also expanded, are few in number. Although the basic patterns of MG staining reactions are similar, *K. heterochaeta* has an intense dorsal green stain on the peristomium, whereas *K. brigittae* **n. sp.** has only a weakly staining reaction that de-stains rapidly.

Biology. No specimens were observed to have gametes.

Distribution. Antarctica, Weddell Sea, in slope depths, 1510–2387 m; Powell Basin, 1942–1956 m; South Shetland Islands, 2009 m; Bellingshausen Sea, 3801 m.

***Kirkegaardia olgahartmanae* new species**

Figures 34–36

Tharyx sp. Hartman 1967: 230.

Material examined. Antarctica, East Antarctic Peninsula, Larsen Ice Shelf A Area, Greenpeace Trough, RVIB *Nathaniel B. Palmer* Cruise 2000-03, Sta. 04, 64°49.209'S, 060°32.033'W, 668 m, 16 May 2000, Smith McIntyre grab, coll. J.A. Blake, **holotype** (LACM-AHF Poly 8939); Sta. 07, 64°43.523'S, 060°045.771'W, 839 m, 18 May 2000, coll. J.A. Blake, 4 **paratypes** (LACM-AHF Poly 8940); Sta. 22, 64°46.632'S, 060°21.557'W, 868 m, 20 May 2000, coll. J.A. Blake, 2 **paratypes** (LACM-AHF Poly 8941).—West Antarctic Peninsula, Bransfield Strait, *Eltanin* Sta. 430, 62°38'S, 59°37'W, 07 January 1963, 681–1409 m, 20 specimens (USNM 56084); R/V *Polarstern*, Cruise ANT XV/2, Sta. MIC 55, 62°16.45'S, 57°35.20'W, 8 Dec 1997, 1940 m, coll. H. Sahling, 3 specimens, (ZMH P-27816); Sta. MIC 86, 62°16.70'S, 57°34.90'W, 18 Dec 1997, 2000 m, coll. H. Sahling, 1 specimen (ZMH P-27817); R/V *Polarstern*, Cruise ANT-XXII/3, ANDEEP III, Sta. 152-2, multicore, 62°19.95'S 57°54.00'W, 1996 m, 23 March 2005, 6 specimens (ZMH P-27818); Sta. 152-4, multicore, 62°19.98'S, 57°54.00'W, 2000 m, 23 March 2005, 9 specimens (ZMH P-27819).

Description. A moderate sized species, holotype from Larsen Ice Shelf Area complete, 10 mm long, 0.6 mm wide for 40 setigerous segments; specimens from ANT XV/2 and *Eltanin* collection larger, up to 19.8 mm long, 0.9 mm wide across anterior setigers, 1.1 mm wide across ovigerous segments, 0.8 mm wide across narrow posterior end, for approximately 75 setigers. Entire body coiled with largest specimens forming a distinct twisted spiral (Fig. 35A), with shape likely due to habitus position in mud ball within which worms live. Color in alcohol: light tan with areas of dark brown pigment on lateral sides of peristomium and some pigment inter-segmentally outlining some parapodia, and patches elsewhere along body; some branchiae dark brown; dorsal tentacles not pigmented.

Pre-setigerous region as long as wide, together with thickened first four to five setigers of thoracic region forming thick, bulbous anterior front of the worm. Body of all specimens with broad thoracic region with short segments followed abruptly by long twisted or spiraled abdominal middle section with large segments (Fig. 35A), some moniliform segments filled with large eggs more than 200 µm in diameter (Fig. 34B); abdominal segments thickest in moniliform reproductive segments; posterior segments narrow to weakly expanded, bearing pygidium with terminal anus and short ventral rounded lobe (Figs. 34C–D; 35C).

Prostomium wider than long, broadly triangular in dorsal view (Fig. 34A), narrowing, bluntly rounded on anterior margin (Figs. 34A–B; 35B); eyes absent; nuchal organs not apparent. Peristomium robust, about as wide as long (Fig. 34B), slightly wider in smaller specimens; smaller specimens including holotype with 2–3 distinct annular rings; grooves less distinct in larger specimens where peristomium often appears smooth with only a vague suggestion of annulations (Fig. 34B); short proboscis everted on most specimens (Fig. 34A–B). Dorsal tentacles long, thick, arising from posterior border of peristomium (Fig. 34A–B). First pair of branchiae lateral to tentacles, also on posterior margin of peristomium (Fig. 34A–B); second pair of branchiae on setiger 1, arising dorsal to notosetal fascicle (Fig. 34A); anteriormost branchiae short, wrinkled in appearance; some branchiae extremely long, suggesting they protrude from burrow into overlying water.

Thoracic region with 8–10 segments in smaller specimens including holotype (Fig. 34A), up to 15 segments in largest specimens (Fig. 34B; 35B); thoracic region thickened ventrally at setigers 1–3 in smaller specimens (Fig. 35B) and 1–5 in larger ones (Fig. 34B); thoracic parapodia shifted dorsally, but not overlying dorsal surface (Fig. 34A–B); abdominal parapodia laterally positioned (Fig. 34C–D).

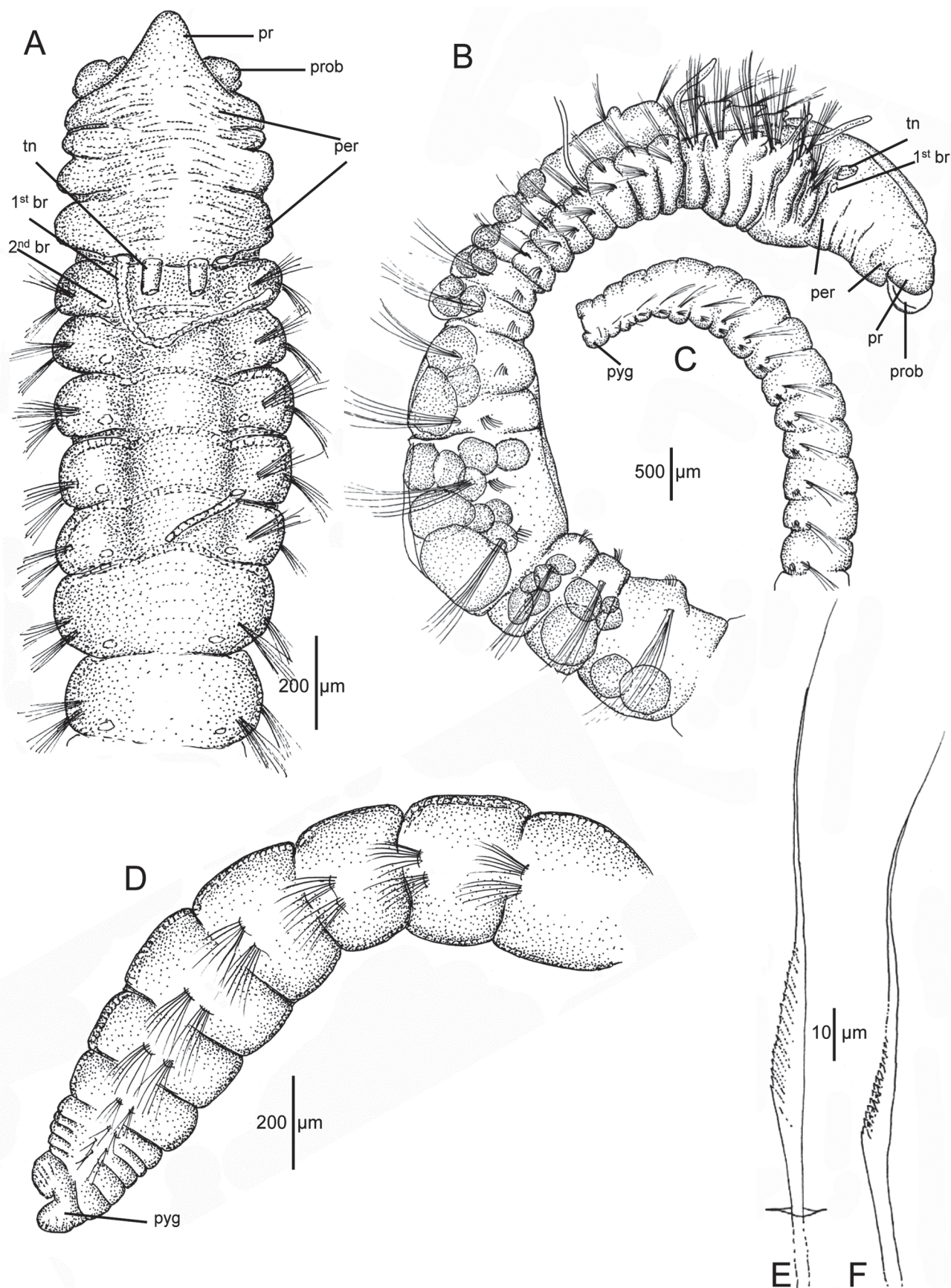


FIGURE 34. *Kirkegaardia olgahartmanae* n. sp., A. anterior end, dorsal view; B, anterior end, right lateral view; C, same specimen, posterior end; D, posterior end, right lateral view; E–F, serrated neurosetae from abdominal setiger. A, D, holotype (LACM-AHF Poly 8939); B–C, E–F, BIC Sta. 55 (ZMH P-27816).

Parapodia well developed in thoracic setigers; anteriorly set off from dorsum and adjacent segments by deep grooves; setiger 1 reduced in largest specimens, shifted ventrolaterally, with presetal notopodial lamella (Fig. 34B); middle and posterior segments with parapodia reduced to low setal tori from which setae arise; setal fascicles of noto- and neuropodia close together throughout most of body.

Notosetae long simple capillaries throughout, with up to 15 setae per fascicle in anterior setigers (Fig. 35E), decreasing to 7–10 posteriorly; neurosetae all simple capillaries on first nine setigers; with 2–3 short denticulated capillaries appearing among longer capillaries from setiger 10, completely replacing long, smooth capillaries by setiger 14, continuing to posterior end; denticulated capillaries numbering 12–24 per fascicle along most of body, depending on size of worms, arranged in two rows (Fig. 35E), reduced to 9–10 in far posterior setigers; denticulated capillaries with broad, expanded blade bearing sawtooth or denticulated edge tapering to narrow tip (Figs. 34E–F, 35F–G).

Methyl Green stain. The stain is concentrated on the venter of the last 3–4 thoracic segments of the Larsen specimens, on what appear to be light-colored glandular areas; it de-stains rapidly. The Bransfield Strait specimens have a weak pattern that develops on the pre-setigerous area with a clear dorsal peristomial area surrounded by bands that extend ventrally (Fig. 35D); segmental areas generally do not retain any stain.

Etymology. This species is named after Dr. Olga Hartman, polychaete systematist, whose monographs on Antarctic polychaetes inspired this author; Dr. Hartman also identified the first specimens of this species as *Tharyx* sp. in Hartman (1967).

Remarks. *Kirkegaardia olgahartmanae* n. sp. is an unusual cirratulid that is closely related morphologically to *K. luticastella* and *K. jumarsi* n. sp. in having a modified body and inhabiting mud balls in deep-water sediments. *Kirkegaardia luticastella* has been described by Jumars (1975) and Blake (1996; this study) and can be readily compared with the two new species described herein. Superficially, all three species are similar in having an expanded pre-setigerous area and thoracic region, enlarged ovigerous segments in anterior abdominal segments of females, a narrow coiled and twisted posterior end, and denticulated capillary neurosetae first present from an anterior segment.

The three species differ in the development of the thoracic parapodia and exposure of the dorsal surface. In *K. luticastella*, the thoracic parapodia are elevated but only weakly overlie the relatively smooth dorsal surface. In *K. jumarsi* n. sp., the thoracic segments are narrow with the parapodia dorsally elevated over the dorsal midline such that the dorsal surface forms a shallow dorsal groove between the parapodia. In *K. olgahartmanae* n. sp., the parapodia are well developed but do not extend dorsally above the mid-dorsal surface but leave a relatively smooth dorsum. Other differences between the three species are in the morphology of the peristomium. In both *K. luticastella* and *K. jumarsi* n. sp. there is only a single groove separating the peristomium into two annular rings; in *K. luticastella*, this groove is best developed in smaller specimens and obscured or difficult to see in larger specimens; in *K. jumarsi* n. sp. the posterior ring is laterally subdivided into three or four narrow ridges and the dorsal surface of the first ring is elevated into a domed crest, while ventrally it forms an enlarged lip around the mouth. In *K. olgahartmanae* n. sp. there are two or three annular rings, best seen in smaller specimens, but visible with careful observation in larger specimens.

Methyl Green staining reactions differ between the three species. The holotype of *K. jumarsi* n. sp. did not exhibit any MG staining reaction at all. In *K. luticastella*, the tip of the prostomium retained stain as did the posterior borders of the two peristomial rings in the specimen from northern California, but there was no stain retention on the thoracic segments. In contrast, some specimens of *K. olgahartmanae* n. sp. exhibited a banded pattern around a clear dorsal area on the peristomium; in addition, stain concentrated on the venter of three or four thoracic segments.

Biology. *Kirkegaardia olgahartmanae* n. sp. is the third species described in a group of closely related deep-water cirratulids that occupy spiral burrows within mud balls that can be observed on the surface. Mr. Heiko Sahling, who provided specimens of *K. olgahartmanae* n. sp. from the Bransfield Strait for examination, said in correspondence that: “The mudballs were observed with a video-sled in a very broad area; porewater and chlorophyll profiles indicate a strong bioturbation caused by these tiny creatures.” The mud ball habitat described by Mr. Sahling for these specimens is similar to that reported for *K. luticastella* from the San Diego Trough by Jumars (1975 as *Tharyx luticastellus*).

As part of sediment results of the ANDEEP III survey, Howe *et al.* (2007) described the sedimentary environment from the Bransfield Strait Station 152 based on sediment cores, seafloor plan view images and

sediment profile images. The site consists of about 45 cm of homogenous, watery, olive grey silty mud described by these authors as “fine-grained, intensely bioturbated with abundant biogenic mud balls” formed by the cirratulid polychaete, herein described as *K. olgahartmanae* **n. sp.** The surface sediment texture is fine-grained mud consisting of 69% silt, 28% clay, and 3% sand. No phytodetritus or lithic clasts were visible and no bottom-current activity was noted from the camera or video. The sediment is rich in siliceous biogenic material consisting largely of diatoms and radiolarians (Howe *et al.* 2007).

Surface photographs of the seafloor at Station 152 were provided by Dr. Robert Diaz (Virginia Institute of Marine Science). The photographs were taken at a height of about 0.8 m above the bottom and imaged a visible area of approximately 8000 cm² or 0.8 m² (Fig. 36A–B). By dividing the images into quadrants and counting the mud balls in each area, a maximal concentration of visible mud balls of approximately 198 per image or 1/40.4 per cm² is estimated. Extrapolating these results, there are approximately 250 mud balls visible over a surface area of 1 m² of the seafloor. However, there are likely many more present because tubes or structures formed by smaller worms would not be visible in the images. Sediment profile images (SPI) or sideways views of the sediment, also provided by Dr. Diaz, are 15 cm wide x 20 cm deep. An example of the full width of such a SPI image is shown in Fig. 36C. Three large mud balls and two smaller ones are visible; additional mud balls are in three other SPI images (Fig. 36D–F). Individual mud balls are irregular in shape and range from 1.6–2.6 cm in width based on direct measurements from the SPI images. Individual mud balls are 3-dimensional, however, and extend below the surface of the seafloor. The large mud ball to the right in Fig. 36C, for example, is approximately 3 cm in height x 2.6 cm in width. Within the mud balls, the worms likely live in a twisted or spiraled tube based on the shape of individual worms and description of the habitus of *K. luticastella* (Jumars 1975). All of the mud balls exhibit an irregular surface with lateral silty outgrowths that appear to be similar to the “digitiform external protuberances” of the tube within the mud ball as described by Jumars (1975: 343). However, for *K. olgahartmanae* **n. sp.**, these outgrowths are silty and bulbous in appearance (Fig. 36C–F) rather than elongate protuberances.

Worms from the *Eltanin* survey in the Bransfield Strait were encased in a membranous tube material similar to that of *K. tessellata* and *K. baptistae* described elsewhere in this paper. This suggests that the worms produce spiraled burrows that are lined with a soft, pliable, membranous mucoid substance. In describing *K. luticastella* Jumars (1975: 342) stated that “The body is helically coiled as far as its mid-length, where it is bent through 180°, and is again coiled parallel with the anterior half, so that the head and pygidium are juxtaposed. Preserved specimens retain this posture, and are withdrawn into the lower half of the robust, mucus-lined tubes.” This spiral or twisted arrangement of the body appears to be similar in *K. olgahartmanae* **n. sp.** because the bodies of complete specimens are clearly spiraled and also have filamentous tube materials lining their burrows within the mud balls.

The type collection of *K. olgahartmanae* **n. sp.** was selected from samples collected from the Greenpeace Trough in the Larsen Ice Shelf A area on the east side of the Antarctic Peninsula in an area newly open to the sea due to collapse of the ice shelf; it was discovered by multibeam bathymetry during a survey in May 2000 (Domack *et al.* 2001). This habitat differs significantly from the Bransfield Strait location where the worms form dense populations visible by the mud balls on the surface of the seafloor. In contrast, the seafloor in the Greenpeace Trough appeared to be in a constant state of disturbance due to the presence of numerous deposit-feeding elasapoid holothurians, *Elpidia glacialis* Théel, 1876, which were observed by video to be constantly moving over the surface. Several of the holothurians were observed on the surface of 10 x 10 x 50 cm megacore tubes collected from the site (Blake & Maciolek unpublished). Presumably as a result of this type of disturbance, dense colonies of *K. olgahartmanae* were not present at this location. These nearshore sediments were described from 20–25 cm cores as coarse-grained, overlying fine-grained silt and clay size sediments with depth (Gilbert & Domack 2003). The type collection consists of seven specimens collected from three locations in the trough. No specimens were collected in the nearby Prince Gustav Channel or other locations in the Larsen Ice Shelf A area outside the Greenpeace Trough. However, there have been few benthic surveys along the eastern side of the Antarctic Peninsula and it is likely that with further sampling the species will be found to have a more extensive distribution.

Large eggs measuring up to 220 µm in diameter were observed in specimens from all surveys. The eggs occurred mostly in the large moniliform segments of the anterior abdominal region. Large eggs suggest a direct development for the species.

Distribution. Known from both sides of the Antarctic Peninsula: Larsen Ice Shelf A area, from a nearshore trough, 668–868 m; from the Bransfield Straits, 681–2000 m, where the species occupies mud balls visible on the surface.

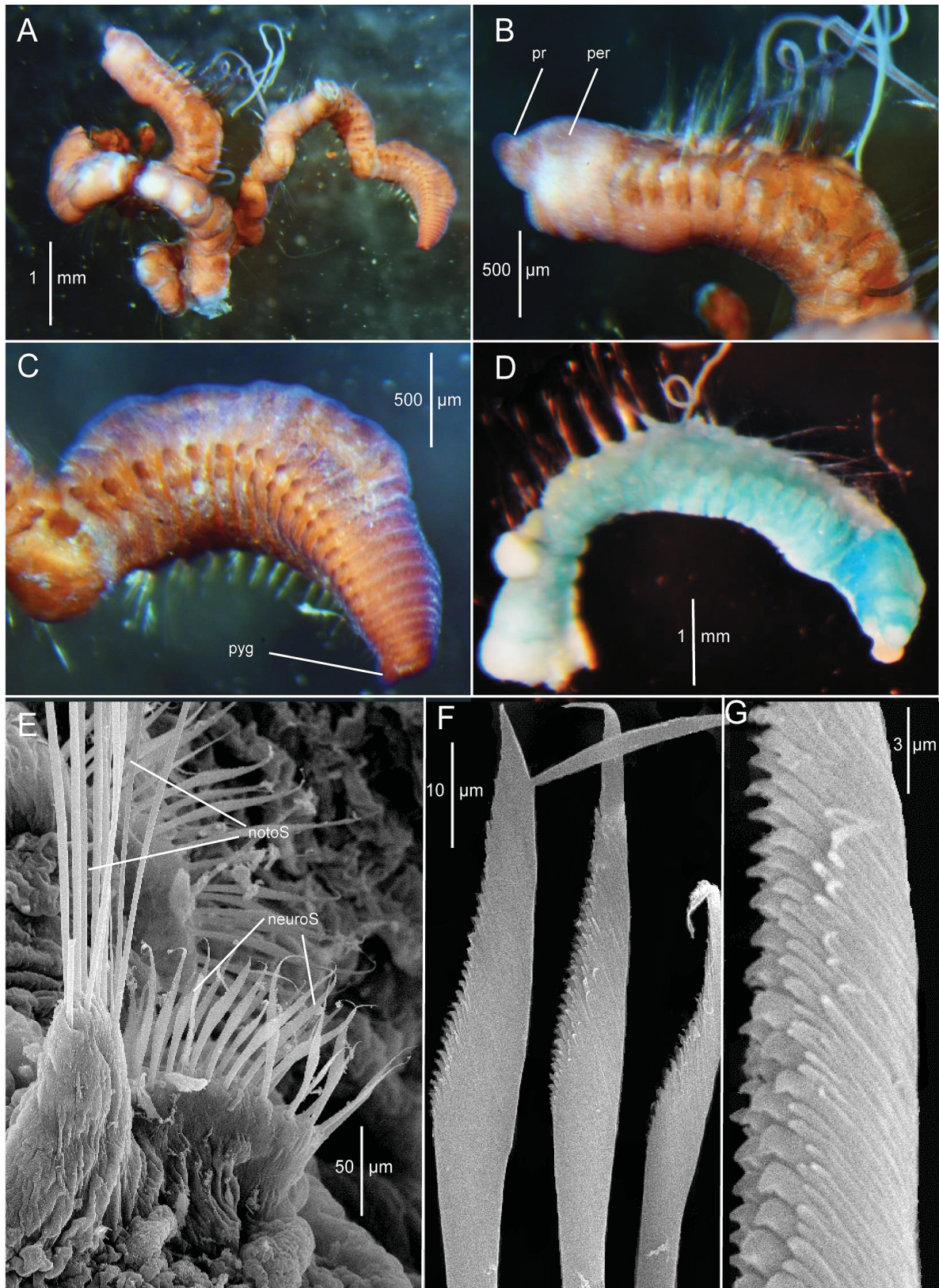


FIGURE 35. *Kirkegaardia olgahartmanae* n. sp. A–D, Photomicrographs: A, Lateral view of entire worm; B, same specimen, anterior end in detail; C, same specimen, posterior end in detail; D, specimen stained with Methyl Green.—E–G, SEMs: E, anterior abdominal parapodium showing noto- and neurosetal fascicles; F, denticulated neurosetae (seta on left with broken tip), G, detail of another neurosetae detail of denticles along cutting edge of blade. A–C, specimen from ANDEEP Sta. 152 (ZMH P-27819), stained with Shirlastain A; D, specimen from Sta. MIC-55 (ZMH P-27816), stained with Methyl Green; E–G, specimen from Sta. ANDEEP III Sta. 152 (SEM, JAB).

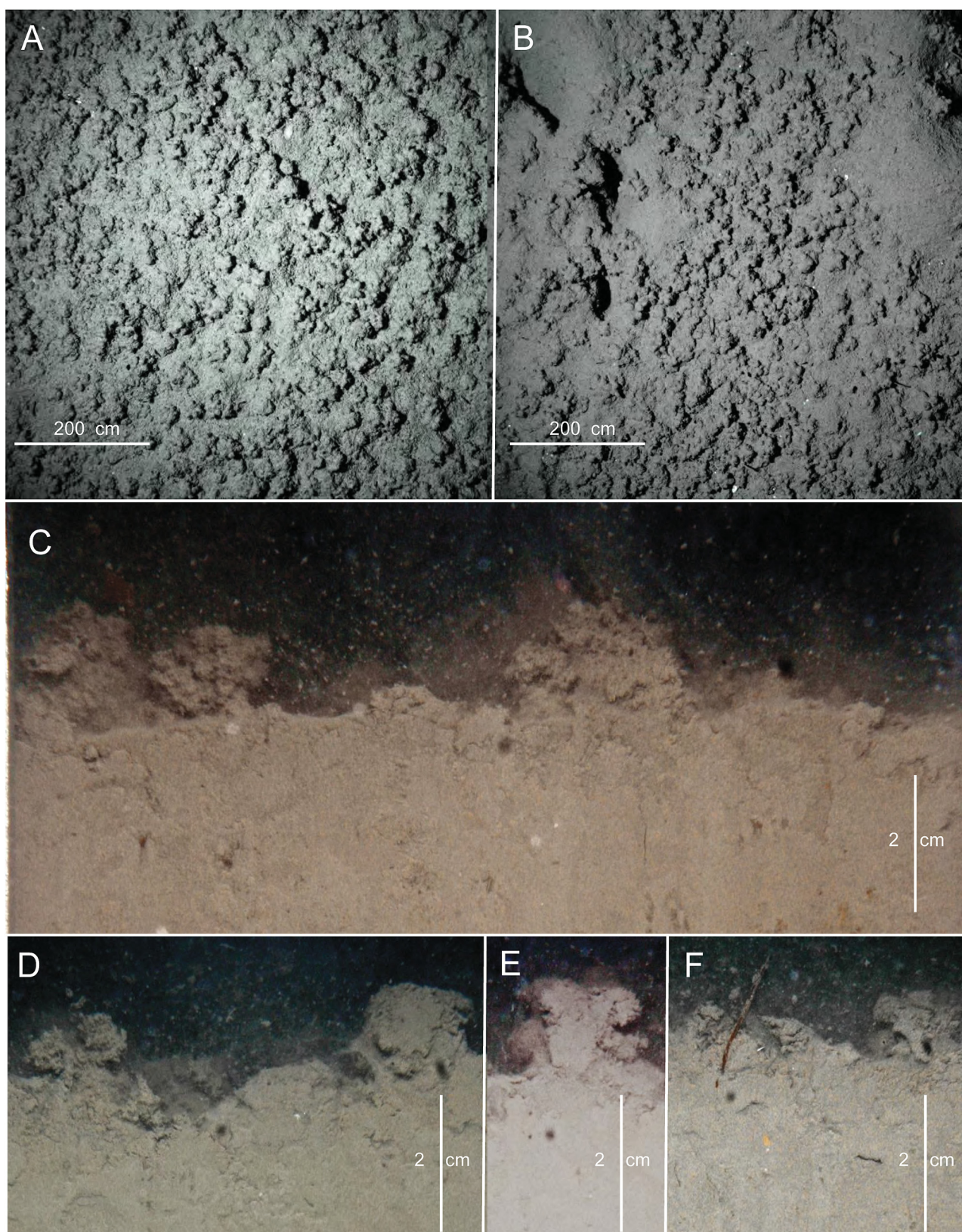


FIGURE 36. *Kirkegaardia olgahartmanae* n. sp. Mud ball habitat at ANDEEP III Sta. 152 in the Bransfield Strait, Antarctica: A–B, planview 35-mm images taken 0.8 m above the seafloor.—C–F, sediment profile 35 mm images: C, 15 cm wide image, showing upper 4.5 cm and mud balls on the surface; D–F, separate images edited to show individual mud balls. Images courtesy of Dr. Robert J. Diaz.

Discussion

Twenty-four species of the new genus *Kirkegaardia* have been reviewed or described in this paper; in addition, eight other species were described or redescribed by Blake (1996) and Dean & Blake (2009). With 38 currently recognized species, *Kirkegaardia* is now one of the largest genera in the Cirratulidae. Based on these observations, it is very clear that a more comprehensive list of characters and character states are available to compare and contrast these species than previously recognized. It is also apparent that the genus consists of at least three distinct groups of species and several other species for which relationships have yet to be fully defined. In the sections that follow, important taxonomic characters for *Kirkegaardia* species are reviewed and groups of closely related species are compared. A comprehensive table of all presently known species of *Kirkegaardia* has been assembled in order for readers to understand and use the characters to identify species and species groups (Table 1). A separate table detailing different MG staining patterns helps elucidate an important technique for separating closely related species (Table 2). In addition, given the wide geographic area treated in this paper, a summary of the known distributions and depth ranges of species of *Kirkegaardia* by area is presented (Table 3).

Taxonomic characters important for identification of *Kirkegaardia* species. *Body shape.* Species of *Kirkegaardia* in general have three different body shapes. The most common is long and thin with little in way of enlargement of the thoracic region. These species typically have an elongate pre-setigerous region and abdominal segments that are often moniliform. The far posterior end may also be enlarged to varying degrees or not at all.

The second type of body shape is seen with the mud ball worms in which the pre-setigerous and thoracic regions are greatly enlarged and bulbous suggesting a means to block the tube opening or to open cracks in the mud; the rest of the body is narrow, twisted, and often with moniliform segments.

The third type of body shape in *Kirkegaardia* species is where the pre-setigerous area merges with the thoracic region, which itself is typically enlarged ventrally; body segments are typically narrow anteriorly, large and often moniliform in the abdomen, and crowded again in far posterior segments, sometimes forming an expanded region. This type of body form is also found in other bitentaculate cirratulids.

Nature of the peristomium. The pre-setigerous region of many species of *Kirkegaardia* is elongate and narrow suggesting an adaptation for burrowing through soft sediments. Such an elongate pre-setigerous area does not occur in other cirratulids and serves to readily recognize the genus when a specimen having this characteristic is encountered. Other species of *Kirkegaardia* have a more typical cirratulid pre-setigerous region that may only be slightly longer than wide. The mud ball worms have a very short, bulbous, and enlarged peristomium.

The peristomium itself is typically incised with grooves serving to divide it into two or more distinct annular rings. The presence and number of these rings are important taxonomic characters. In some species, the rings are difficult to discern unless stained with Shirlastain A or through the use of an SEM. However, in some species, the entire pre-setigerous area may be completely smooth without any evidence of grooves or rings.

The peristomium may also have a dorsal crest or ridge developed to varying degrees. In some species, this is limited to the first half of the peristomium; in other species, the ridge extends the entire length of the peristomium from the prostomium to the beginning of the thoracic segments. In a few species, the peristomial ridge continues and more or less merges with a similar crest along the dorsum of the thoracic region.

Position of the dorsal tentacles and anterior branchiae. The dorsal tentacles of most species of *Kirkegaardia* are positioned near the end of the posterior part of the peristomium. In a few species there is a posterior peristomial extension that carries the tentacles to a medial location on the first setiger. Typically, the tentacles are close to one another along the mid-dorsum of the peristomium. The first pair of branchiae are lateral to the tentacles and either at the posterior margin of the peristomium, a groove between setiger 1 and peristomium, or directly on setiger 1. Rarely, the first branchiae occur anterior to the tentacles. When the first branchiae occur on setiger 1, there may also be a second pair on the same segment. This arrangement suggests that a segment has been fused or lost.

Position of the thoracic parapodia and occurrence of a mid-dorsal thoracic channel. A distinctive feature of many species of *Kirkegaardia* is that the thoracic parapodia are dorsally elevated such that they overlie the mid-dorsal surface producing a channel along the thorax. Such an arrangement is not known for other cirratulids. The branchiae of individual segments along the channel are usually located at the dorsal most edge of each elevated parapodium, thus overlying the mid-dorsal channel. In some species such as *K. dorsobranchialis*, the branchiae remain in this medial position even in abdominal segments after the parapodia have shifted laterally.

TABLE 1. Taxonomic Characters for 38 Species of *Kirkegaardia*.

Species	Prostomium	No. of Peristomial Annular rings	Peristomial dorsal ridge or crest	Pre-setiger length/width ratio	Dorsal thoracic channel	Mid-dorsal thoracic ridge	Location of dorsal tentacles	Distribution	References
<i>acunai</i> (Dean & Blake, 2009)	Triangular, broad	4	Present	1.2:1	Present	Present	Posterior margin of peristomium	Pacific Costa Rica, 9–46 m	Dean & Blake (2009)
<i>antelaxa</i> (Dean & Blake, 2009)	Conical, narrow	3	Absent	1.3:1	Absent	Absent	Posterior margin of peristomium	Pacific Costa Rica, 18 m	Dean & Blake (2009)
<i>annulosa</i> (Hartman, 1961)	Triangular, short	2–4	Present,	2:1	Present	Present	Posterior margin of peristomium	Off New England, upper slope depths 250–550 m	Hartman (1965); this study
<i>anterobranchiata</i> (Magalhães & Bailey-Brock, 2013)	Triangular, broad	3	Present	1.1:1	Absent	Absent	Medial to setiger 1	Off Oahu, Hawaii, 20 m	Magalhães & Bailey-Brock (2013)
<i>antonbruunae</i> n. sp.	Short, narrow, tapering	3–5	Absent	1.3:1	Absent	Present on a few anterior setigers	In notch, post. margin of peristomium	Off Peru, slope depths, 737–1000 m	This study
<i>aphelecephala</i> (Hutchings & Murray, 1984)	Triangular, narrow	0	Absent	2.1:1	Absent	Absent	Posterior margin of peristomium	New South Wales, Australia, 4–12 m	Hutchings & Murray (1984)
<i>ariotrachelia</i> n. sp.	Triangular, tapering to narrow tip	3: 1 large, 2 narrow	Absent	1.4:1	Absent	Absent	On second annular ring	Off Peru in slope depths, 520–805 m	This study
<i>baptisteae</i> (Blake, 1991)	Triangular, pointed	0–3	Absent	1.5:1	Absent	Absent	Post. extension of peristomium	U.S. Atlantic shelf & slope; 30–640 m	Blake (1991); This study
<i>brigitteae</i> n. sp.	Conical, short, bluntly rounded apex	0	Present, on first half of peristomium; rest smooth	2.5:1	Present	Present, narrow	Posterior. of peristomium	Antarctic seas in slope depths, 1500–3864 m	This study
<i>carinata</i> n. sp.	Triangular, tapering to rounded apex	0	Absent	1.8:1	Present	Present	Posterior of peristomium	Off northern California, in slope depths, 2820–3864 m	This study
<i>carolina</i> n. sp.	Triangular, tapering to narrow apex	3	Present	1.7:1	Absent	Absent	Posterior margin of peristomium	North Carolina slope; 500–1000 m	This study

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TABLE 1. (Continued)

Species	Prostomium	No. of Peristomial Annular rings	Peristomial dorsal ridge or crest	Pre-setiger length/width ratio	Dorsal thoracic channel	Mid-dorsal thoracic ridge	Location of dorsal tentacles	Distribution	References
<i>carrikeri</i> (Dean & Blake, 2009)	Triangular, pointed tip	3	Present	1.5:1	Absent	Absent	Posterior margin of peristomium	Pacific Costa Rica, 11–24 m	Dean & Blake (2009)
<i>chilensis</i> n. sp.	Short, oval, rounded on apex	0–3	Absent	1.9:1	Present	Present	Posterior margin of peristomium	Off Chile, slope depths, 624–957 m.	This study
<i>cristata</i> n. sp.	Triangular, narrow, elongate	4	Present	1.6:1	Present	Present	Posterior margin of peristomium	NE Pacific Ocean, Puget Sound, 20 m.	This study
<i>cryptica</i> (Blake, 1996)	Triangular, narrowing to a point	0–2	Absent	1.9:1	Present	Absent	Posterior margin of peristomium	California continental shelf, 92–585 m.	Blake (1996); Not Dean & Blake (2009); Magalhães & Bailey-Brock (2013)
<i>dorsobranchialis</i> (Kirkegaard, 1959)	Triangular, blunt on anterior margin	0	Absent	1:1 holotype; 1.5:1 paratypes	Present	Absent	Posterior margin of peristomium	West and South Africa, 20–120 m.	Kirkegaard (1959); Laubier (1966); This study
<i>dutchae</i> n. sp.	Conical, blunt on tip	0–3	Present	1.5:1	Absent	Absent	Posterior margin of peristomium.	NE Pacific, Puget Sound, 14–82 m	This study
<i>elongata</i> (Dean & Blake, 2009)	Triangular, broad	6	Absent	2.8:1	Absent	Absent	Posterior margin of peristomium	Pacific Costa Rica, 18 m.	Dean & Blake (2009)
<i>fragilis</i> n. sp.	Conical, tapering to rounded tip	0	Absent	1.7:1	Absent	Absent	Posterior margin of peristomium	Abyssal Pacific, 4858–4879 m	This study
<i>franciscana</i> n. sp.	Conical, rounded apex	0–2	Present	1.5:1	Absent	Absent	Posterior margin of peristomium	Off northern California, in slope depths, 2237–2983 m	This study

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TABLE 1. (Continued)

Species	Prostomium	No. of Peristomial Annular rings	Peristomial dorsal ridge or crest	Pre-setiger length/width ratio	Dorsal thoracic channel	Mid-dorsal thoracic ridge	Location of dorsal tentacles	Distribution	References
<i>giribeti</i> (Dean & Blake, 2009)	Triangular, broad	5–6	Low ridge, peristomium	2.75:1	Present, wide	Absent	Posterior margin of peristomium	Pacific Costa Rica; off Ecuador; intertidal to 90 m.	Dean & Blake (2009); This study
<i>hampsoni</i> n. sp.	Triangular, narrow	0–2	Present	2.0:1	Present	Present	Posterior margin of peristomium	U.S. Atlantic shelf, 30–150 m	This study
<i>hanaumaensis</i> (Magalhães & Bailey-Brock, 2013)	Conical, rounded at apex	0	Absent	1.5:1	Absent	Absent	Posterior margin of peristomium	South Shore Oahu, Hawaii, in coral rubble	Magalhães & Bailey-Brock (2013)
<i>heroae</i> n. sp.	Triangular, tapering to narrow tip	3: 1 large, 2 narrow	Crest present over 2 posterior rings	1.3:1	Absent	Absent	Medial, on 3 rd peristomial. ring	Off Tiera del Fuego, Staten Isl., 33–41 m	This study
<i>heterochaeta</i> (Laubier, 1961)	Triangular, short, blunt on tip	0–2	Present, anterior one-half of peristomium	2.2:1	Present	Present	Posterior margin of peristomium	Mediterranean, shallow subtidal	Laubier (1961, 1966); This study
<i>jumarsi</i> n. sp.	Short, rounded	2	Absent, “domed”	1:1	Present	Absent	Posterior margin of peristomium	Peru-Chile Trench, 5430 m	This study
<i>kladara</i> n. sp.	Conical, rounded on apex	0	Present, narrow, continuous from prostomium	1.8:1	Present	Present	Posterior margin of peristomium	North Carolina slope, 500–1000 m	This study
<i>lueddedgei</i> (Magalhães & Bailey-Brock, 2015)	Conical, tapering	2	Absent	1.6:1	Present, shallow	Absent	Posterior margin of peristomium	Marianas Isl., Guam, 14–17 m	Magalhães & Bailey-Brock (2015)
<i>luticastella</i> (Jumars, 1975)	Short, blunt	2	Absent	1:1	Present, shallow	Absent	Posterior margin of peristomium	Offshore California, 1200–2637 m	Jumars (1975); Blake (1996); This study

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TABLE 1. (Continued)

Species	Prostomium	No. of Peristomial Annular rings	Peristomial dorsal ridge or crest	Pre-setiger length/width ratio	Dorsal thoracic channel	Mid-dorsal thoracic ridge	Location of dorsal tentacles	Distribution	References
<i>marpetersenae</i> (Lezzi <i>et al.</i> , 2015)	Triangular, blunt on tip	4	Absent	1.3:1	Absent	Absent	Posterior extension of peristomium to level of setiger 1	Italy, Ionian Sea, 4 m.	Lezzi <i>et al.</i> (2015)
<i>morae</i> (Elias, Rivero & Orensanz, 2016)	Conical, acute	3	Present, second half of peristomium	?	Absent	Absent	Posterior margin of peristomium, lateral to dorsal crest	SW Atlantic, off Argentina, low water	Elias <i>et al.</i> (2016)
<i>olgahartmanae</i> n. sp.	Triangular, blunt	0–3, based on size and preservation	Absent	1:1	Absent	Absent	Posterior margin of peristomium	Off Antarctic Peninsula, 650–2000 m	This study
<i>neotesselata</i> n. sp.	Triangular, short	4	Present	1.5:1	Present	Present	Posterior margin of peristomium	New England, upper slope, 255 m	This study
<i>secunda</i> (Banse & Hobson, 1968)	Conical, pointed, narrow	1–3	Absent	1.8:1	Broad, smooth	Absent	Posterior margin of peristomium	NE Pacific, shallow water	Banse & Hobson (1968); Blake (1996)
<i>serratiseta</i> (Banse & Hobson, 1968)	Triangular, pointed	3	Absent	1.1:1	Absent	Absent	Medial on posterior extension of peristomium	NE Pacific, 9–84 m.	Banse & Hobson (1968); Blake (1996); This study
<i>setosa</i> (Dean & Blake, 2009)	Conical, narrow	5	Present	1.3:1	Absent	Absent	Posterior margin of peristomium	Pacific Costa Rica, 18 m.	Dean & Blake (2009)
<i>sibilinea</i> (Blake, 1996)	Triangular wedge shaped	3	Absent	1.8:1	Low, broad	Absent	Posterior medial border or chaetous segment	Southern California, 7–10 m.	Blake (1996)
<i>tesselata</i> (Hartman, 1960)	Triangular, pointed	2–4	Absent	1.4:1	Absent	Present	Posterior margin of peristomium	California, shelf depths	Hartman (1960); Blake (1996); This study

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TABLE 1. (Continued)

Species	First pair of branchiae	Ventral longitudinal grooves or ridges	Denticulate notosetae	Denticulate neurosetae	Posterior end	Distribution	References
<i>acunai</i> (Dean & Blake, 2009)	Setiger 1	Absent	Present; abdominal setigers 24–34	Present, 2 rows, abdominal setigers 22–33	Not expanded	Pacific Costa Rica, 9–46 m	Dean & Blake (2009)
<i>antelata</i> (Dean & Blake, 2009)	Setiger 1	Absent	Absent	Present, 1 row, then 2 rows, abdominal setiger 34	Unknown	Pacific Costa Rica, 18 m	Dean & Blake (2009)
<i>annulosa</i> (Hartman, 1961)	Lateral to dorsal tentacles	Absent	Present, abdominal setigers, ~ 50	Present, abdominal segments, ~ setiger 45	Expanded	Off New England, upper slope depths 250–550 m	Hartman (1965); this study
<i>anterobranchiata</i> (Magalhães & Bailey-Brock, 2013)	Anterior to dorsal tentacles on last annular ring	Absent	Present, abdominal setigers 40–44	Present, setigers 13–16	Tapering, not expanded	Off Oahu, Hawaii, 20 m	Magalhães & Bailey-Brock (2013)
<i>antonbruunae</i> n. sp.	Setiger 1	Abdominal segments with mid-ventral ridge	Absent	Present abdominal segments ~ setiger 35	Narrow	Off Peru, slope depths, 737–1000 m	This study
<i>aphelocephala</i> (Hutchings & Murray, 1984)	Lateral to dorsal tentacles	Absent	Present, ~ setiger 50	Present, ~ setiger 40	Weakly inflated	New South Wales, Australia, 4–12 m	Hutchings & Murray (1984)
<i>ariotrachela</i> n. sp.	Setiger 1	Prominent groove along entire body	Present, mid-body segments	Present, mid-body segments	Unknown	Off Peru in slope depths, 520–805 m	This study
<i>baptisteae</i> (Blake, 1991)	Lateral to dorsal tentacles	Weak groove posterior end	Present, anterior abdominal setigers ~15–20	Present abdominal setigers ~15–20	Expanded	U.S. Atlantic shelf & slope; 30–640 m	Blake (1991); This study
<i>brigitteae</i> n. sp.	Lateral to dorsal tentacles	Posterior segments with low mid-ventral ridge	Present, anterior abdominal setigers, 12–14	Present, anterior abdominal setigers, 12–14	Greatly expanded	Antarctic seas in slope depths, 1500–3864 m	This study
<i>carinata</i> n. sp.	Lateral to dorsal tentacles in groove between peristomium & setiger 1	Absent; thin mid-ventral line visible	Present, anterior abdominal setigers, 17–18	Present, anterior abdominal setigers, 16–17	Unknown	Off northern California, in slope depths, 2820–3864 m	This study

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TABLE 1. (Continued)

Species	First pair of branchiae	Ventral longitudinal grooves or ridges	Denticulate notosetae	Denticulate neurosetae	Posterior end	Distribution	References
<i>carolina</i> n. sp.	Setiger 1	Absent	Absent	Present setiger 15–20 or anterior abdominal region	Weakly expanded, narrow elongate	North Carolina slope; 500–1000 m	This study
<i>carrikeri</i> (Dean & Blake, 2009)	Setiger 1	Shallow groove posterior end	Absent	Present abdominal setigers 31–33	Expanded with weak ventral groove	Pacific Costa Rica, 11–24 m	Dean & Blake (2009)
<i>chilensis</i> n. sp.	Lateral to dorsal tentacles on peristomium.	Abdominal segments with shallow groove and low ridge	Absent	Present mid-abdominal segments; ~setiger 30	Narrow	Off Chile, slope depths, 624–957 m.	This study
<i>cristata</i> n. sp.	Lateral to dorsal tentacles on peristomium	Groove present anterior abdominal segments	Present, posterior abdominal segments, ~setiger 45	Present, posterior abdominal segments, ~setiger 45	Narrow	NE Pacific Ocean, Puget Sound, 20 m.	This study
<i>cryptica</i> (Blake, 1996)	Lateral to dorsal tentacles on peristomium	Medial groove, posterior setigers	Present, ~ setiger 21	Present, abdominal segments, ~ setiger 22	Weakly expanded	California continental shelf, 92–585 m.	Blake (1996); Not Dean & Blake (2009); Magalhães & Bailey-Brock (2013)
<i>dorsobranchialis</i> (Kirkegaard, 1959)	Lateral to dorsal tentacles on peristomium	Absent	Present, posterior thoracic setigers ~15–20	Present, posterior thoracic setigers ~15–20	Unknown	West and South Africa, 20–120 m.	Kirkegaard (1959); Laubier (1966); This study
<i>dutchae</i> n. sp.	Setiger 1 + 2 nd pair on setiger 1	Absent	Absent	Present ~ setigers 35–40	Expanded	NE Pacific, Puget Sound, 14–82 m	This study
<i>elongata</i> (Dean & Blake, 2009)	Setiger 1 + 2 nd pair on setiger 1	Absent	Present, setiger 24	Present, setiger 22	Expanded	Pacific Costa Rica, 18 m.	Dean & Blake (2009)
<i>fragilis</i> n. sp.	Setiger 1	Absent	Present about setiger 20	Present, setiger 20	Expanded	Abyssal Pacific, 4858–4879 m	This study
<i>franciscana</i> n. sp.	Lateral to dorsal tentacles on peristomium	Absent	Present, mid-abdominal segments	Present, mid abdominal segments, ~setiger 30	Narrow	Off northern California, in slope depths, 2237–2983 m	This study

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TABLE 1. (Continued)

Species	First pair of branchiae	Ventral longitudinal grooves or ridges	Denticulate notosetae	Denticulate neurosetae	Posterior end	Distribution	References
<i>giribeti</i> (Dean & Blake, 2009)	Lateral to dorsal tentacles on peristomium	Absent	Present, ~ 24–25	Present, ~ setigers 22–24	Expanded	Pacific Costa Rica; off Ecuador; intertidal to 90 m.	Dean & Blake (2009); This study
<i>hampsoni</i> n. sp.	Lateral to dorsal tentacles on peristomium	Shallow groove in posterior segments	Present, mid-abdominal setigers, ~setiger 50	Present, mid-abdominal segments, ~setiger 50	Expanded	U.S. Atlantic shelf, 30–150 m	This study
<i>hanamaensis</i> (Magalhães & Bailey-Brock, 2013)	Setiger 1 + 2 nd pair on setiger 1	Absent	Present, far posterior setigers	Present, setigers 30–35	Weakly expanded	South Shore Oahu, Hawaii, in coral rubble	Magalhães & Bailey-Brock (2013)
<i>heroae</i> n. sp.	Setiger 1 + 2 nd pair on setiger 1	With deep mid-ventral groove	Present ~ setiger 30	Present ~ setiger 30	Expanded	Off Tierra del Fuego, Staten Isl., 33–41 m	This study
<i>heterochaeta</i> (Laubier, 1961)	Lateral to dorsal tentacles between peristomium & setiger 1	Absent	Present, anterior abdominal setigers 11–19	Present, setigers 11–19	Expanded	Mediterranean, shallow subtidal	Laubier (1961, 1966); This study
<i>jumarsi</i> n. sp.	Lateral to dorsal tentacles between peristomium & setiger 1	Absent	Absent	Present setiger 13	Unknown	Peru-Chile Trench, 5430 m	This study
<i>kladara</i> n. sp.	Setiger 1	Absent	Present, anterior abdominal setigers ~10–12	Present, anterior abdominal ~setigers 10–12	Enlarged, greatly expanded	North Carolina slope, 500–1000 m	This study
<i>lueldredgei</i> (Magalhães & Bailey-Brock, 2015)	Setiger 1 + 2 nd pair on setiger 1	Shallow thoracic groove	Present, anterior abdominal 10–12	Present, anterior abdominal 10–12	Weakly expanded	Marianas Isl., Guam, 14–17 m	Magalhães & Bailey-Brock (2015)
<i>luticastella</i> (Jumars, 1975)	Lateral to dorsal tentacles posterior peristomium	Absent	Absent	Present, anterior abdominal setigers 9–10	Narrow	Offshore California, 1200–2637 m	Jumars (1975); Blake (1996); This study
<i>marypetersenae</i> (Lezzi <i>et al.</i> , 2015)	Anterior to dorsal tentacles at level of setiger 1	Absent	Absent	Present, setiger 17	Dorso- ventrally flattened	Italy, Ionian Sea, 4 m.	Lezzi <i>et al.</i> (2015)

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TABLE 1. (Continued)

Species	First pair of branchiae	Ventral longitudinal grooves or ridges	Denticulate notosetae	Denticulate neurosetae	Posterior end	Distribution	References
<i>morae</i> (Elias, Rivero & Orensanz, 2016)	Posterolateral to dorsal tentacles on setiger 1	Absent	Present setiger 1	Present setiger 1	Expanded laterally, dorsally inflated	SW Atlantic, off Argentina, low water	Elias <i>et al.</i> (2016)
<i>olgahartmanae</i> n. sp.	Lateral to dorsal tentacles on peristomium	Absent	Absent	Present ~setiger 10	Weakly expanded	Off Antarctic Peninsula, 650–2000 m	This study
<i>neotesseleta</i> n. sp.	Setiger 1	Absent	Absent	Present, setiger 11–12	Expanded	New England, upper slope, 255 m	This study
<i>secunda</i> (Banse & Hobson, 1968)	Posterior to dorsal tentacles on peristomium	Absent	Absent	Present, ~ setiger 25	Expanded	NE Pacific, shallow water	Banse & Hobson (1968); Blake (1996)
<i>serratiseta</i> (Banse & Hobson, 1968)	Setiger 1 + 2 nd pair on setiger 1	Groove present abdominal segments	Absent	Present, mid-abdominal segments, ~ 100–125.	Flattened, with ventral groove	NE Pacific, 9–84 m.	Banse & Hobson (1968); Blake (1996); This study
<i>setosa</i> (Dean & Blake, 2009)	Setiger 1	Absent	Absent	Present, posterior segments, ~ 90	Unknown	Pacific Costa Rica, 18 m.	Dean & Blake (2009)
<i>siblina</i> (Blake, 1996)	Setiger 1 + 2 nd pair on setiger 1	Absent	Absent	Present, anterior abdominal segments	Expanded, large	Southern California, 7–10 m.	Blake (1996)
<i>tessellata</i> (Hartman, 1960)	Setiger 1	Absent	Absent	Present, anterior abdominal segments	Expanded	California, shelf depths	Hartman (1960); Blake (1996); This study

The mid-dorsal channel, when developed, may be either a simple, smooth depression or may have a dorsal ridge developed to varying degrees. In *K. heterochaeta* and *K. annulosa*, the entire mid-dorsal surface of the channel is raised, whereas in other species such as *K. hamptoni* **n. sp.** and *K. brigitteae* **n. sp.**, there is a separate, narrow mid-dorsal ridge along the surface of the channel. In *K. carolina* **n. sp.**, the ridge is broken into separate mounds on each segment.

Dorsal and ventral grooves. Apart from the mid-dorsal channel and ridges along the dorsum of the thoracic segments of many species, dorsal grooves elsewhere along body are absent. Ventrally, grooves and ridges such as occur in other cirratulid genera are rare. A distinct mid-ventral groove occurs in *K. araiotrachela* **n. sp.** and *K. serratiseta* but these species are unusual and outliers in many respects. Several species such as *K. baptistae* and *K. dutchae* **n. sp.** have a ventral groove or channel in their expanded far posterior region.

Abdominal segmentation. The majority of species of *Kirkegaardia* transition from narrow thoracic segments to abdominal segments that become longer and either blocky, rounded, or moniliform in shape. Far posterior segments again become narrower, sometimes forming an expanded posterior section that bears a simple pygidium, usually with a small ventral lobe. Exceptions are species such as *K. serratiseta* that have numerous crowded segments throughout and a deep ventral groove.

Morphology of setae. The genus *Monticellina* (here renamed *Kirkegaardia*) was originally defined by Blake (1991) as differing from other bitentaculate genera by lacking spines but having capillaries with a distinctly denticulated or sawtooth edge along one margin. The denticles, even if minute, of the majority of species are readily recognized as being distinct from fibrils that emerge irregularly from capillaries of other cirratulids. For the great majority of species now referred to *Kirkegaardia*, this character holds up well. For the mud ball worms and species of the *K. baptistae-tesselata* group, the denticulated capillaries are typically limited to the neuropodia. For most of the species related to *K. heterochaeta* and *K. dorsobranchialis*, denticulate setae occur in both noto- and neuropodia and with setal fascicles arranged *vis-à-vis*. The denticles themselves vary widely among the species and are generally not well characterized due to different methods of observation. With light microscopy, the sharply pointed and widely spaced teeth on capillaries of *K. cryptica* are obviously different from the numerous and tightly spaced teeth of *K. hamptoni* **n. sp.** and many other species. Not many of the known species have been studied with SEM and the limitations of light microscopy preclude observation of fine details. For example, SEM observations in the present study demonstrate that the denticles of setae of *K. hamptoni* **n. sp.** are indeed limited to the setal margin with the rest of the shaft being relatively smooth (Fig. 12H–I). In contrast, while the main denticles of *K. brigitteae* **n. sp.** are also along the margin, associated with the denticles are smaller blunted lateral fibril endings that extend along the entire side of the shaft (Fig. 31E–F). A similar situation is found in the mud ball worm *K. olgahartmanae* **n. sp.**, except that the main tooth has only 1–2 lateral teeth, but with long grooves denoting individual fibrils extending along the sides of the shaft (Fig. 33F–G). Magalhães & Bailey-Brock (2013) used SEM to depict a similar structure on serrated setae of their species *K. anterobranchiata* from Hawaii. Such setal detail obviously provides finer resolution to separate one species from another, but given the limited access to and associated expense of operating an SEM, this capability is often not available. The use of SEM will be important to resolve the status of cirratulids such as *K. araiotrachela* **n. sp.**, *K. heroeae* **n. sp.**, and *K. serratiseta* described in this paper as not generally agreeing the morphology of *Kirkegaardia* species.

Location of modified setae along the body. The exact segment on which simple capillaries transition to modified denticulated setae is usually considered an important character to identify individual species. However, unless the modified setae begin consistently on a single segment there is usually a range of segments where one must look for these and they are often not easy to find. The starting segment for these setae typically varies with the size of the worm; *Kirkegaardia morae* is the only species described where the denticulated setae are reported to begin on setiger 1 (Elias *et al.* 2016). The larger type collection of the mud ball worm *K. luticastella* was reported to have a thoracic region with 10–11 setigers with modified neurosetae beginning on setiger 10, or the end of the thoracic region (Blake 1996); on the other hand, the smaller specimen of the same species reported in this paper had only seven thoracic setigers, but with denticulated neurosetae from setiger 10 or an anterior abdominal segment. When the modified setae begin further back on the body there is a greater range of starting points and an exact count may be highly variable among different sizes of worms resulting reduced value of an exact segment count. Therefore, it may be more useful to simply document the part of the body where the modified setae first appear: (1) thoracic segments or (2) anterior, middle, or posterior abdominal segments.

TABLE 2. Methyl Green staining areas on species of *Kirkegaardia**

Species/Character	Prostomium	Peristomium	Thoracic segments	Abdominal venter	Abdominal lateral
<i>acunai</i>	Absent	Paired thin blue lines outline mid-dorsal ridge.	Ventral granular blue bands on setigers 10–16, less distinct more anteriorly.	Mid-ventral line on individual segments in post thorax.	Absent
<i>annulosa</i>	Absent	Staining lightly; de-staining rapidly.	Posterior half of thoracic region several broad stripes forming dark blue patch on venter, most obvious on last 3–6 thoracic setigers; these stripes extend dorsally up and over parapodia becoming narrow and dorsolateral on individual segments. Weak narrow transverse lines of stain also evident on sunken dorsal surface of the thorax.	Ventrally, narrow line of green extends posteriorly from the thoracic region along narrow mid-ventral line, broken into separate spots on some specimens.	Lateral inter-segmental spots or patches present on most abdominal segments (Figs. 6B–C); distinctive for this species.
<i>antelaxa</i>	Absent	Absent	Absent	Absent	Absent
<i>anterobranchiata</i>	Intense	Intense stain surrounding unstained area.	Broad bands on posterior margins of venter, extending dorsally over thoracic parapodia.	Bands from thoracic segments continuing on anterior abdominal venter.	Absent
<i>antonbruunae</i> n. sp.	Absent	Absent	Absent	Absent	Absent
<i>apheloccephala</i>	Unknown	Unknown	Unknown	Unknown	Unknown
<i>ariotrachela</i> n. sp.	Light green overall	Absent	Absent	Absent	Absent
<i>baptisteae</i>	Absent	Absent	Absent	Absent	Absent
<i>brigitteae</i> n. sp.	Absent	Overall diffuse green retained; darker posterior dorsal patch developed to varying degrees.	Thoracic segments with bands of blue extending from border of mid-dorsal channel ventrally and up and around opposite side; middle and posterior segments most deeply stained as broad blue bands; parapodia not stained.	mid-ventral spot or short longitudinal band.	Abdominal segments with bright green stain retained laterally on each parapodium.
<i>carinata</i> n. sp.	Absent	Mid-dorsal elongate oval patch extends down lateral sides.	Venter of thoracic region with dark blue-staining segmental bands extending dorsally to mid-dorsal ridge; most of venter solid blue.	Absent	Parapodia of abdominal segments stain heavily producing lateral patches on each segment.
<i>carolina</i> n. sp.	Weak stain on tip.	Absent	Narrow intersegmental grooves of thoracic region retain stain.	Absent	Absent
<i>carrikeri</i> n. sp.	Absent	Absent	Narrow transverse bands across venter of thoracic segments.	Absent	Absent
<i>chilensis</i> n. sp.	Absent	Absent	Venter of thorax stains lightly	Absent	Absent

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TABLE 2. (Continued)

Species/Character	Prostomium	Peristomium	Thoracic segments	Abdominal venter	Abdominal lateral
<i>cristata</i> n. sp.	Absent	Absent	Ventral surface of last 5–6 thoracic segments staining intensely as a large patch.	Absent	Absent
<i>cryptica</i>	Absent	Absent	Thorax with broad light bands from parapodia down and around venter; concentrated on posterior one-third.	Absent	Lateral patches posterior to setal fascicles.
<i>dorsobranchialis</i>	Tip staining dark green.	Evenly speckled light green.	Thoracic segments with diffuse ventral greenish area; also on anterior dorsum and dorsolateral areas of thorax.	Elongate mid-ventral spot on each segment, absent on posterior segments.	Absent
<i>dutchae</i> n. sp.	Weak retention; tip not stained	Absent	Distinct transverse segmental bands across venter of thorax, extending dorsally to parapodia; deepest stain on 3–4 posteriormost thoracic segments.	Absent	Lateral intersegmental vertical bands or patches on anterior abdominal segments.
<i>elongata</i>	Absent	Absent	Green stripe on anterior margin of last 11–19 thoracic segments.	Absent	Absent
<i>fragilis</i> n. sp.	Light green	Absent	Absent	Absent	Absent
<i>franciscana</i> n. sp.	Stains intensely merging with peristomial pattern	Lateral and dorsal sides of peristomium with deep reticulated turquoise pattern; 2 longitudinal grooves on either side stain deep green.	Ventral and lateral sides of thoracic parapodia with reticulated turquoise bands.	Reticulated pattern on venter.	Reticulated pattern on ventral side continues laterally up and onto dorsum.
<i>giribeti</i>	Absent	Absent	Absent	Absent	Absent
<i>hampsoni</i> n. sp.	Absent	Prominent dorsal patch and lateral lines of light green.	8–10 thoracic segments with distinct ventral bands of dark blue extending dorsally to near mid-dorsal channel; 4–6 bands remaining prominent, and last to de-stain.	Prominent mid-ventral longitudinal line or spot present anterior abdominal segments.	Thin lines in intersegmental grooves on dorsal side of abdominal segments.
<i>hanaumaensis</i>	Absent	Absent	Intersegmental thoracic bands on setigers 4–12.	Absent	Absent
<i>heroeae</i> n. sp.	Absent	Absent	Middle of thorax with 3–4 segments with deep turquoise band completely encircling body; intersegmental spaces staining darker turquoise.	Absent	Absent

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TABLE 2. (Continued)

Species/Character	Prostomium	Peristomium	Thoracic segments	Abdominal venter	Abdominal lateral
<i>heterochaeta</i>	absent	Dark dorsal patch; lightly stained down lateral sides.	Middle and posterior thoracic segments dark blue with broad bands from mid-dorsum down both sides around venter.	Medial spot or line on individual segments.	Weak intersegmental lines.
<i>jumarsi</i> n. sp.	Absent	Absent	Absent	Absent	Absent
<i>kladara</i> n. sp.	Present on tip	Absent	Middle and posterior thoracic segments with distinctive ventral pattern extending dorsally to parapodia; diffuse turquoise speckles in middle and larger speckles posteriorly;	Absent	Abdominal segments with parapodia staining green
<i>lueldredgei</i>	Absent	Absent	Venter and sides of thorax distinctly stained	Absent	Absent
<i>luticastella</i>	Present anterior margin	Posterior borders of first and second rings.	Absent	Absent	Absent
<i>marypetersenae</i>	Absent	Absent	Absent	Absent	Absent
<i>morae</i>	Absent	Darker	Intersegmental line; mid-ventral line	Absent	Absent
<i>olgahartmanae</i> n. sp.	Absent	Some specimens with a weak pattern developing on pre-setigerous area with a clear dorsal peristomial area surrounded by bands extending ventrally.	Stain concentrating on venter of last 3–4 thoracic segments of Larsen specimens on what appear to be light colored glandular areas; de-staining rapidly.	Absent	Absent
<i>neotesselata</i> n. sp.	Present	Absent	No stain on anterior thoracic segments; distinct bands on anterior ventral border of posterior thoracic segments, each band extends dorsally encircling each segment up to the parapodia.	Stripes from thoracic region continue on to anterior abdominal region.	Absent
<i>secunda</i>	Absent	Absent	Absent	Absent	Absent
<i>serratiseta</i>	Absent	Absent	Ventral glandular area retaining weak green stain after differentiation.	Absent	Absent
<i>setosa</i>	Absent	Absent	Weak ventral stain on glandular part of thorax.	Absent	Absent
<i>siblina</i>	Absent	Absent	Light ventral bands across thorax.	Absent	Absent
<i>tesselata</i>	Absent	Absent	Small specimens with weak stain on venter of thorax.	Absent	Absent

*Reports of species having uniform green or blue along the body are considered as having no distinct pattern present and are listed as "Absent" for individual categories; "Unknown" denotes a species where methyl green staining was not tested.

Tube and burrow structure. Three basic tube morphologies are identified among species of *Kirkegaardia*. (1) the most common type of tube is simply a fine silt covering suggesting that the worms establish temporary tubes as part of their feeding and burrowing activity. In some species such as *K. kladura* **n. sp.**, fine silt particles are sometimes retained on the body. (2) Species in the *K. baptisteae-tesselata* group produce a more elaborate tube structure consisting of mucoid materials that surround the worms and have openings through which the branchiae and/or dorsal tentacles project at various places along the body. There appear to be two types of these so-called tessellated or tattered tubes. The more common consists of soft, pliable membranous materials such as occur in *K. tessellata* and *K. baptisteae*; these are easily removed from the worms after preservation leaving the specimens in relatively good condition. Another type has been observed in *K. neotesselata* **n. sp.** and *K. sp. A* in which the tubes consist of thicker and more tightly adhering materials that are difficult to remove without damaging the worms. Further, upon preservation these worms are typically twisted due to the tight tubes and emerging branchiae. (3) The most unusual type of tube found in *Kirkegaardia* species are the mud balls in which the worms occupy twisted or spiraled burrows within an accumulated housing of soft silty mud. All three described mud ball species are from deep water: *K. luticastella* from off California, *K. jumarsi* **n. sp.** from the Peru-Chile Trench, and *K. olgahartmanae* **n. sp.** from off the Antarctic Peninsula. Another species has been reported, but not named, from the Oman margin, Arabian Sea by Levin & Edesa (1997). Interestingly, the burrows within the mud balls of *K. olgahartmanae* **n. sp.** are also lined with the same type of soft tessellated tube coverings reported for *K. tessellata* and relatives.

Methyl Green staining reactions. A summary of MG staining patterns for the known species of *Kirkegaardia* are presented in Table 2. Several staining reactions appear to be characteristic of many *Kirkegaardia* species including: (1) intense staining, often blue or turquoise, of the ventral surface of the thoracic region that usually extends dorsally up the sides to near the dorsal surface; the parapodia themselves will either stain or be clear; (2) a mid-ventral abdominal green line or patch on individual segments; (3) lateral abdominal patches of green that are typically associated with the parapodia; (4) peristomial staining is rare and variable when it occurs. For example, *K. heterochaeta*, *K. hampsoni* **n. sp.**, and *K. carinata* **n. sp.** have a strong and diagnostic peristomial staining reaction, whereas *K. dorsobranchialis* has a peristomial pattern that it is weak and diffuse; (5) stain is rarely retained on the prostomium.

***Kirkegaardia* species groups.** Species of *Kirkegaardia* may be divided into three distinct groups and several outlier species that are either not well described or exhibit characters of other genera.

Kirkegaardia dorsobranchialis-heterochaeta group (12 species). This is the classic group of *Kirkegaardia* species that includes the original species first described by Kirkegaard (1959), Hartman (1960), and Laubier (1961). All have thoracic parapodia elevated above the dorsal surface producing a channel between the notopodia. All of these species also have an elongate pre-setigerous area that is either entirely smooth or modified with a dorsal ridge and/or annular rings. All species in this group have denticulated capillaries in both the noto- and neuropodia. Species in this group include: *K. annulosa*, *K. brigitteae* **n. sp.**, *K. carinata* **n. sp.**, *K. cryptica*, *K. chilensis* **n. sp.**, *K. cristata* **n. sp.**, *K. dorsobranchialis*, *K. elongata*, *K. giribeti*, *K. hampsoni* **n. sp.**, *K. heterochaeta*, and *K. kladara* **n. sp.**

This group may be further divided into four subgroups based on peristomial morphology:

- (1) *K. dorsobranchialis*, *K. carinata* **n. sp.**, *K. chilensis* **n. sp.**, and *K. cryptica*. These four species have an entirely smooth peristomium with no dorsal ridge.
- (2) *K. brigitteae* **n. sp.** and *K. heterochaeta*. Both species have an elongate, smooth peristomium, with a peristomial ridge limited to the anterior half.
- (3) *K. annulosa*, *K. kladara* **n. sp.**, *K. cristata* **n. sp.**, and *K. hampsoni* **n. sp.** These four species have a peristomium with a dorsal ridge along its entire length.
- (4) *K. giribeti* and *K. elongata*. Both of these species have an unusually long peristomium, lacking a dorsal ridge but incised with 5–6 annular rings.

Kirkegaardia baptisteae-tesselata group (18 species). This is the largest group of species and includes those that do not have thoracic parapodia elevated above the dorsal surface—a mid-dorsal channel is not produced and the dorsal surface is typically smooth, although a dorsal ridge is sometimes developed. The pre-setigerous area of

these species is not especially long and narrow but is of an appearance more typical of other bitentaculate cirratulids; dorsal ridges and annular rings are present or absent. Most species in this group have denticulations on the neurosetae but not the notosetae. Seven species in this group (*) have been found to have tessellated or tattered mucoid tubes through which branchiae project; since tubes are typically removed by technicians during the sample processing, it is likely that other species would be found with similar tubes if that character were to be noted during sample processing. Previously only *K. tessellata* was described with these tubes; therefore, it has been widely reported when, in effect, other species are possible; it probable that *K. tessellata* is actually limited to California. As part of this study, *K. neotesselata* **n. sp.** from the New England continental slope and specimens of *Kirkegaardia* sp. A from the Mediterranean Sea have been found to have thick, heavy and tightly adhering tessellated tubes that are difficult to remove from the worms without damage. In contrast the tubes of *K. tessellata* and others such as *K. antonbruunae* **n. sp.**, *K. baptistae*, *K. carolina* **n. sp.**, *K. dutchae* **n. sp.**, and *K. fragilis* **n. sp.** have tubes that are thin, pliable and are easily removed with little or no damage to the worms. Species included in this group include: *K. acunae*, *K. antelaxa*, *K. anterobranchiata*, *K. antonbruunae** **n. sp.**, *K. aphelocephala*, *K. baptistae**, *K. carolina** **n. sp.**, *K. carrikeri*, *K. dutchae** **n. sp.**, *K. fragilis** **n. sp.**, *K. luedredgei*, *K. marypetersenae*, *K. morae*, *K. neotesselata** **n. sp.**, *K. secunda*, *K. setosa*, *K. siblina*, and *K. tessellata**.

Kirkegaardia luticastella group, the mud ball worms (3 species). This unique group of deep-water cirratulids have an enlarged pre-setigerous region + anterior thorax and occupy twisted or spiraled burrows within distinct mud balls on the surface of the seafloor. The modified thoracic region has elevated parapodia above a broad dorsal surface that lacks a ridge or crest. Anterior abdominal segments are typically large and moniliform and often packed with large eggs. All three described species have denticulate neurosetae; denticulate notosetae are absent. The three described species are: *K. luticastella*, *K. jumarsi* **n. sp.**, and *K. olgahartmanae* **n. sp.** Another species from the Oman Margin in the Arabian Sea has been reported, but not described (Levin & Edesa 1997).

Outlier species or species not fully characterized (5 species). Six species, three new, do not fall into the three groups detailed above. (1) *K. araiotrachela* **n. sp.** has an unusual body shape, a mid-ventral groove, and in addition to denticulate notosetae has an aristate type of neuroseta that has bristles or denticles only at the abrupt narrowing of the shaft. These setae apparently grade into heavy neuropodial spines similar to those found in species of *Chaetozone*. The posterior end is not known. The species requires further study. (2–3) *Kirkegaardia franciscana* **n. sp.** and *K. hanaumaensis* are small and lack most of the distinctive morphology that characterizes other species of the genus; it is possible they are juveniles. (4) *Kirkegaardia heroae* **n. sp.** has serrated noto- and neurosetae, but these appear to be more like stiff fibril endings rather than the denticles that characterize other species of the genus. Further, the last two annuli on the peristomium are narrow and resemble achaetous segments found in other bitentaculate genera. The thoracic region is unusually long and a ventral groove is present. These features suggest a close relationship with the genus *Aphelochaeta* and the species requires further study. (5) *Kirkegaardia serratiseta* from the northeastern Pacific is more similar to *Aphelochaeta* spp., in having a ventral groove in abdominal segments, crowded segments, and numerous silky capillaries.

Geographic distribution of *Kirkegaardia* species. Globally, 38 named and one provisional species of *Kirkegaardia* are reported from the following areas: (1) Eastern Atlantic including West Africa and the Mediterranean Sea (4 species): *K. heterochaeta*, *K. marypetersenae*, and *K. dorsobranchialis* (+ *Kirkegaardia* sp. A as cf. *tesselata*); (2) SW Atlantic, off Argentina (1 species): *K. morae*; (3) US Atlantic coast (6 species): *K. annulosa*, *K. baptistae*, *K. carolina* **n. sp.**, *K. kladara* **n. sp.**, *K. hampsoni* **n. sp.**, and *K. neotesselata* **n. sp.**; (4) US Pacific coast (10 species): *K. cryptica*, *K. luticastella*, *K. tessellata*, *K. secunda*, *K. siblina*, *K. serratiseta*, *K. dutchae* **n. sp.**, *K. cristata* **n. sp.**, *K. carinata* **n. sp.**, and *K. franciscana* **n. sp.**; (5) Pacific coasts of Central America and South America (9 species): *K. acunai*, *K. antelaxa*, *K. carrikeri*, *K. elongata*, *K. giribeti*, *K. setosa*, *K. antonbruunae* **n. sp.**, *K. chilensis* **n. sp.**, and *K. araiotrachela* **n. sp.**; (6) Hawaii & Central Pacific (3 species): *K. anterobranchiata*, *K. hanaumaensis*, and *K. luedredgei*; (7) Abyssal Pacific (2 species): *K. fragilis* **n. sp.** and *K. jumarsi* **n. sp.**; (8) Antarctica and sub-Antarctica (3 species): *K. heroae* **n. sp.**, *K. brigitteae* **n. sp.**, and *K. olgahartmanae* **n. sp.**; (9) Australia/New Zealand (1 species): *K. aphelocephala*.

Based on this summary, it is clear that significant gaps in knowledge of *Kirkegaardia* species exist for the east coast of South America, the U.S. and Mexican coasts of the Gulf of Mexico, Australia/New Zealand, Southeast Asia, East Africa, and the Indian Ocean. Further, as shown in the next section, the majority of species are from coastal areas less than 200 m in depth. Deep-sea habitats are poorly known.

TABLE 3. Depth distribution of *Kirkegaardia* species.

Species/Depth range (m)	0–50	50–100	100–250	250–500	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	>5000
<i>K. antelaxa</i>	—									
<i>K. aphelocephala</i>	—									
<i>K. carrikeri</i>	—									
<i>K. elongata</i>	—									
<i>K. marypetersenae</i>	—									
<i>K. morae</i>	—									
<i>K. setosa</i>	—									
<i>K. giribeti</i>	—									
<i>K. luelldredgei</i>	—									
<i>K. secunda</i>	—									
<i>K. siblina</i>	—									
<i>K. heroe n. sp.</i>	—									
<i>K. acunai</i>	—									
<i>K. anterobranchiata</i>	—									
<i>K. cristata n. sp.</i>	—									
<i>K. heterochaeta</i>	—									
<i>K. ditichae n. sp.</i>	—									
<i>K. serratiseta</i>	—									
<i>K. dorsobranchialis</i>	—									
<i>K. hanaumaensis</i>	—									
<i>K. hamptoni n. sp.</i>	—									
<i>K. baptisteae</i>	—									
<i>K. cryptica</i>	—									
<i>K. tessellata</i>	—									
<i>K. neotesselata n. sp.</i>	—									
<i>K. annulosa</i>	—									
<i>K. aratotrachela n. sp.</i>	—									
<i>K. chilensis n. sp.</i>	—									
<i>K. carolina n. sp.</i>	—									
<i>K. kladara n. sp.</i>	—									
<i>K. antonbrunae n. sp.</i>	—									
<i>K. olgachartmanae n. sp.</i>	—									
<i>K. laticastella</i>	—									
<i>K. brigiteae n. sp.</i>	—									
<i>K. franciscana n. sp.</i>	—									
<i>K. carinata n. sp.</i>	—									
<i>K. fragilis n. sp.</i>	—									
<i>K. jumarasi n. sp.</i>	—									

Bathymetric depth distribution of species of *Kirkegaardia*. Table 3 shows the bathymetric distribution of the 37 known species of *Kirkegaardia*. Twenty species or 57% occur in waters shallower than 200 m; of these, most are from shallow subtidal depths to no more than 50 m. Ten species range into deeper waters of 500–1000 m. Only seven species occur in depths greater than 1000 m and of these, only two were collected from abyssal depths of 4000 m or greater. Of the seven deep-sea species, six are newly described in this study.

These results suggest that many more species of *Kirkegaardia* await discovery especially in deep-sea habitats. It is noteworthy that the three mud ball species are from deep-water habitats.

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